ORTON MEMORIAL LIBRARY

Orton

ARCTIC

VOLUME 13, NUMBER 4 · DECEMBER 1960

JOURNAL OF THE ARCTIC INSTITUTE OF NORTH AMERICA

THE ARCTIC INSTITUTE OF NORTH AMERICA

The Arctic Institute of North America was founded to further the scientific study and exploration of the Arctic. The Institute provides information on the Arctic through its three offices, awards research grants, and publishes scientific papers and other contributions in its journal *Arctic*. Those interested in this work are invited to become Members. Members receive all numbers of the journal. The Library and Map Collection at the Montreal Office are principally for their use, and they are welcome there and at the other Institute Offices. Membership dues are $5.00 annually. All remittances should be sent to the Montreal Office.

Board of Governors

C. S. Lord, *(Chairman)*, Ottawa, Ont.
D. C. Nutt, *(Vice-Chairman)*, Hanover, N.H.
M. J. Dunbar, *(Secretary)*, Montreal, P.Q.
O. C. S. Robertson, *(Treasurer)*, Washington, D.C.
A. T. Belcher, Ottawa, Ont.
W. S. Benninghoff, Ann Arbor, Mich.
J. C. Case, New York, N.Y.
Henry B. Collins, Jr., Washington, D.C.
Ian McTaggart Cowan, Vancouver, B.C.
Frank T. Davies, Ottawa, Ont.
C. M. Drury, Montreal, P.Q.
Gerald Fitzgerald, Salt Lake City, Utah
F. Kenneth Hare, Montreal, P.Q.
Trevor Lloyd, Montreal, P.Q.
A. E. Porsild, Ottawa, Ont.
Paul Queneau, New York, N.Y.
D. C. Rose, Ottawa, Ont.
Paul A. Siple, Washington, D.C.
O. M. Solandt, Montreal, P.Q.
Walter Sullivan, New York, N.Y.
A. L. Washburn, Hanover, N.H.
Ira L. Wiggins, Stanford, Calif.
J. T. Wilson, O.B.E., Toronto, Ont.
Walter A. Wood, New York, N.Y.

Executive Director

John C. Reed
Montreal

Directors of Offices

Washington — R. C. Faylor
Montreal — M. Marsden

Editor of the Institute Journal *Arctic*

Paul F. Bruggemann

Offices of the Institute

3485 University Street, Montreal 2, P.Q., Canada
1530 P Street, N.W., Washington 5, D.C., U.S.A.
2 East 63rd St., New York 21, N.Y., U.S.A.

ARCTIC

Journal of the Arctic Institute of North America

Vol. 13, No. 4 Published in Montreal, P.Q. **December 1960**

CONTENTS

Cover Picture: Flensing a squareflipper (bearded seal, *Erignathus barbatus)* for the manufacture of skin line, Southampton Island, N. W. T., Canada, 1956. *Photo: A. W. Mansfield*

The Vegetation of Northern Manitoba V. Establishing the Major Zonation. *J. C. Ritchie* 211

Type E Botulism: a Hazard of the North. *Claude E. Dolman* 230

Recent Records of the California Grey Whale *(Eschrichtius glaucus)* along the North Coast of Alaska. *William J. Maher* 257

Notes:

Some Soil Fungi from an Alaskan Tundra Area. *Wm. Bridge Cooke and H. T. Fournelle* 266

Application for the Position as Executive Director of the Boreal Institute of the University of Alberta 270

Institute News:

The Arctic Institute Devon Island Expedition 1960. *Spencer Apollonio* 270

Ellesmere Ice Shelf Project 1960. *R. B. Sagar* 271

Missing Field Party on Great Bear Lake 272

Gifts to the Library 272

Technical Papers of the Arctic Institute 273

Reviews:

A Photo-Reconnaissance Survey of Labrador-Ungava. *J. C. Ritchie* 273

Wonders of the Arctic. *Nora Corley* 275

The World of the Arctic. *J. Keith Fraser* 275

Geographical Names in the Canadian North 276

Index 277

COPYRIGHT REGISTERED 1960

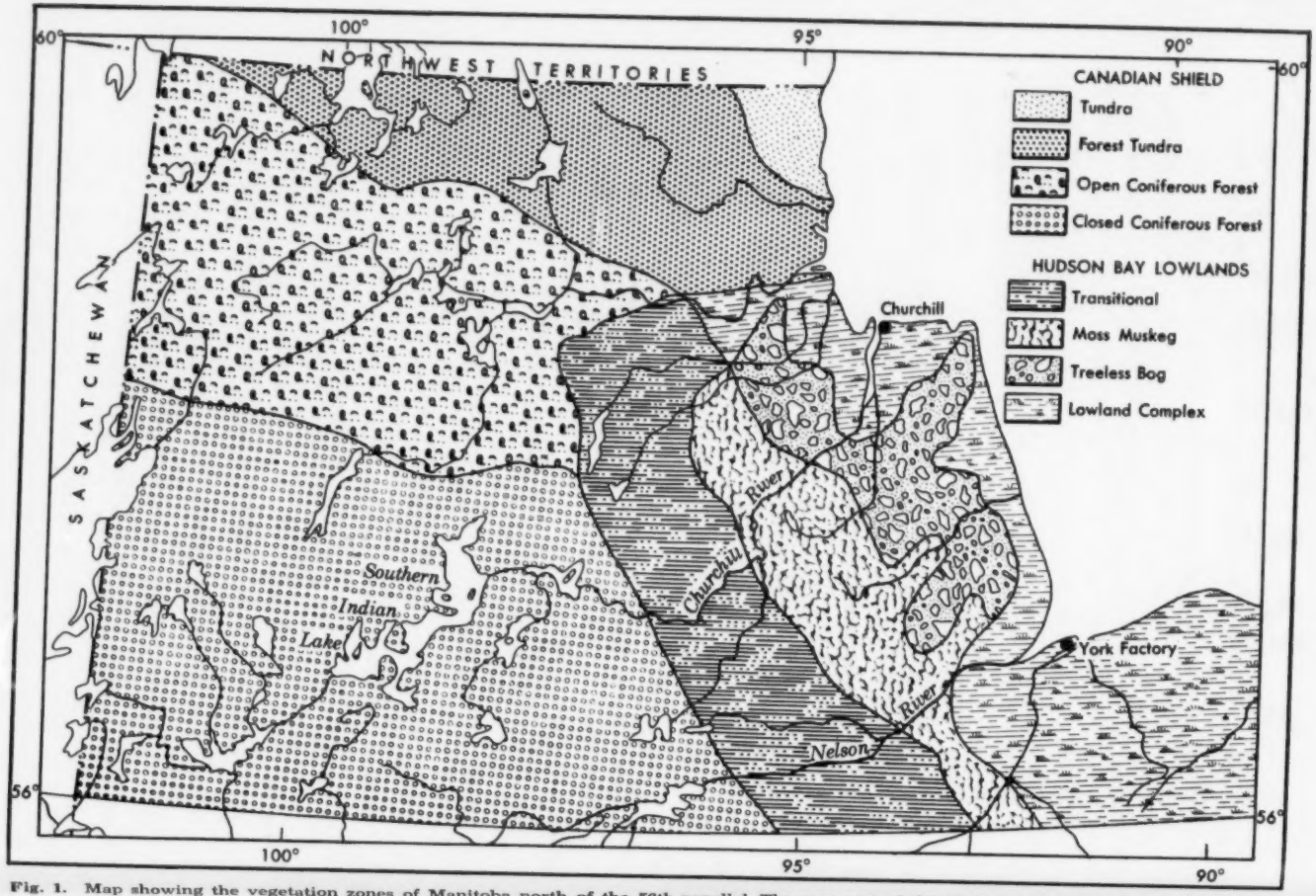


Fig. 1. Map showing the vegetation zones of Manitoba north of the 56th parallel. The area east of the 92nd meridian has not been examined and the suggestion that it is occupied solely by the Lowland Complex Type is tentative.

THE VEGETATION OF NORTHERN MANITOBA
V. ESTABLISHING THE MAJOR ZONATION

J. C. Ritchie*

Introduction

ONE of the first requirements of a study of the vegetation of a large, poorly known region is the compilation of maps showing the extent of the various categories of plant cover. Investigation must begin with extensive work to establish the general configuration of vegetation zones and community types and be followed by detailed intensive study of the composition, structure, dynamics, and ultimately the ecology of the vegetation. In the present investigation extensive and intensive studies have proceeded more or less simultaneously, but the representativeness of the latter can be assessed only after the general work has been done.

The work of Hare and his associates in eastern Canada (Hare 1955, 1959) has given impetus and direction to attempts to map accurately the major zones of vegetation in boreal and arctic North America, but at present there is no reliable map showing the zonation of vegetation in any large region of Canada west of Hudson Bay. As Hare points out our knowledge of vegetation zones in northern Canada has until recently depended solely on the reports of travellers whose observations were often confined to watercourses. However, in the last two decades a rich source of information has become available in the vertical air photographs of much of Canada.

An effort is being made to use this source of information to establish the main boundaries between the zones of vegetation in northern Manitoba. This information is making it possible to compile maps of two types — those showing small areas in detail, at scales of about 1:30,000 (for example, Ritchie 1958), and others of large regions showing the major zones of vegetation. The present report is based on a simple map of the latter type (Fig. 1). Work is in process on a vegetation map of the area dealt with here, using the Topographical Map Sheets (scale 1.500,000) as base maps. It uses methods by which Hare and Taylor (1956) have mapped the vegetation of Labrador-Quebec at the 1:500,000 scale. For the present an area of approximately 300,000 square kilometers (100,000 square miles) is being studied, comprising that part of Manitoba bounded in the north by the District of Keewatin, in the west by Saskatchewan, in the south by the 56th parallel, and in the east by the 92nd meridian (Fig. 2).

Fig. 1. Map showing the vegetation zones of Manitoba north of the 56th parallel. The area east of the 92nd meridian has not been examined and the suggestion that it is coniferous rainforest is based on Canadian Forest Inventory data.

*Department of Botany, University of Manitoba, Winnipeg, Manitoba, Canada.

Before presenting the results, brief reference should be made to work of a similar nature by other investigators in Manitoba, since some of it has been of value in developing the present approach. The fully illustrated, detailed report of Cheney and Brown Beckel (1955) on the Churchill area is of value, and will long be referred to for accurate information on the landforms and vegetation of this particular area. Unfortunately it was never published. Beckel (1958) has applied the methods of air photographic interpretation in a selected area of northwestern Manitoba, in connection with studies of the range of the Barren Ground caribou. Following field work in

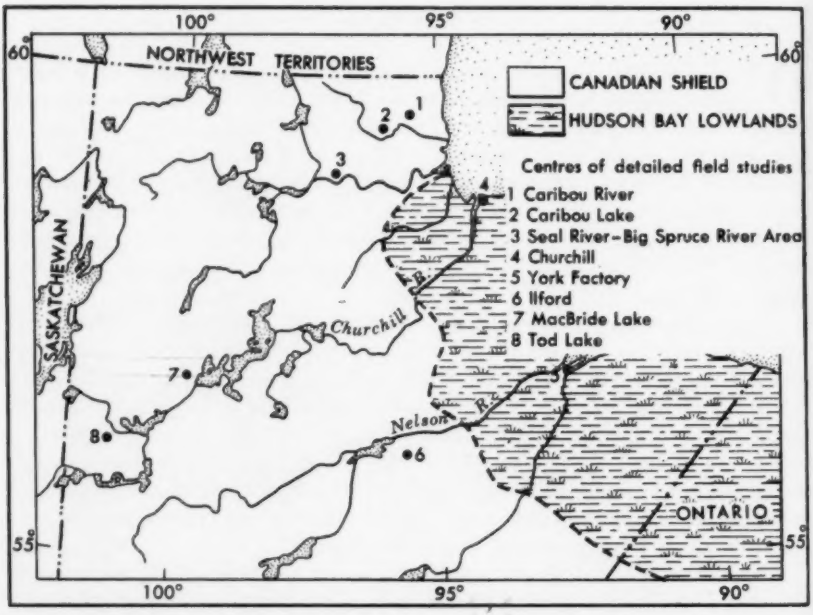


Fig. 2. Map of northern Manitoba showing the main physiographic regions and the centres of detailed field study.

the Churchill area, Radforth (1952) has proposed a completely independent "classification of muskeg" which appears to be designed solely for use in practical applications. It is doubtful if this system will be of use in basic studies of vegetation. As Hustich (1957) and Sjörs (1958) point out, the vegetation and processes of peatlands in the Hudson Bay Lowlands of Canada and those of Europe are remarkably similar, the differences between them being largely of a minor floristic nature. Accordingly, any basic classification of peatlands should take as its starting point the extensive European literatures. Likewise, Radford's "Organic terrain organization from the air" (1958) is of very limited use to the geobotanist.

Methods

Field studies have been carried out in northern Manitoba at the following places and times: MacBride Lake area (56°52′N. 99°57′W.) and Tod Lake area (56°45′N. 101°48′W.) in 1955, Great Island area of Seal River (59°N. 96°45′W.) in 1956, Caribou Lake and Caribou River (59°20′N. 95°10′W.) in 1957, Ilford (56°04′N. 95°36′W.) and Lower Hayes River (57°N. 92°20′W.) in 1959. The Churchill area (58°40′N. 94°W.) was examined in detail in 1954, and for shorter periods in 1956, 1957, and 1958. (Reports on the flora and vegetation of some of these areas are listed in the References). The stations were selected partly because they were thought to be representative and partly for convenience of access and transportation. In addition, sundry flights over the region increased the author's familiarity with the general features of the vegetation.

At each station, a set of vertical air photographs (at scales between 1:20,000 and 1:60,000) was used in the field (and later in the laboratory) and some ability has gradually been acquired in the interpretation of these photographs in terms of vegetation and landforms. Detailed vegetation maps have been compiled for the MacBride Lake, Seal River, Caribou Lake, and Lower Hayes River areas (only the first has been published so far) and in each attempts were made to extend the interpretation and mapping into adjacent unexplored areas. By the end of 1958 a set of "keys" had been prepared, similar to that published (Ritchie 1958), in which summaries are given of the photographic characteristics and physiographic affinities of the vegetation.

It was thought that it might be possible to extend the survey of photographs to the large areas in northern Manitoba where no field work had been done. Accordingly, the National Air Photo Library of the Department of Mines and Technical Surveys, Ottawa was visited in order to examine photographs of areas for which the writer had no coverage. Flight lines were selected that passed from areas examined in the field into unexplored areas, until the entire area had been covered. A flight line of say 100 photographs was studied by examining every photograph rapidly and then studying pairs critically with a magnifying stereoscope at intervals of roughly 10 photographs, especially where a change in vegetation type was suspected. Approximately 3,000 photographs were examined, about 10 per cent of them stereoscopically, and a further 2,000 have been examined in detail in the laboratory. The method depends much on personal experience and familiarity with air photographs. The accuracy of the zonal map (Fig. 1), which cannot be known fully until it has been tested widely in the field and the 1:500,000 maps have been compiled, will be a direct measure of the soundness of the photographic interpretation.

For each photograph or set of continuous photographs, where there was no change in vegetation type, the following information was recorded in abbreviated form: (a) the types of landforms present, indicating the proportions of each; (b) the drainage patterns; (c) the types of vegetation occupying various physiographic positions such as outcrop ridges, eskers, till ridges,

sand plains, drumlins, alluvium, and poorly drained depressions; (d) any evidence of recent disturbance, as by fire. For each set of photographs an estimate (visual) was made of the percentage of upland sites occupied by the various types of vegetation; in the Hudson Bay Lowlands area, where upland sites are rare, all recognizable types of vegetation were given an estimated percentage value. The data were then assembled and the zones of change in vegetation type entered on the base maps. In Fig. 1 these zones are shown as single lines, but nowhere was a boundary between zones so abrupt. Transition zones between the types varied from 20 km. to 100 km. in width, but it is hoped that these can be better defined on the 1:500,000 maps.

A weakness of this method is that the boundaries have been determined by criteria that are neither wholly objective nor precise. The boundaries on the Canadian Shield physiographic region were ascertained as follows:

boundary $\frac{\text{Closed Coniferous Forest (<20 per cent of mesic sites with open-crown forest)}}{\text{Open Coniferous Forest (>20 per cent of mesic sites with open-crown forest)}}$

boundary $\frac{\text{Open Coniferous Forest (<20 per cent of mesic sites with scrub forest)}}{\text{Forest Tundra (>20 per cent of mesic sites with scrub forest)}}$

boundary $\frac{\text{Forest Tundra (<75 per cent of upland sites with heath tundra)}}{\text{Tundra (>75 per cent of upland sites with heath tundra)}}$

In practice the method produces boundaries that indicate actual changes in vegetation physiognomy, but it does not take into account the important fact that the effects of fires have been so widespread in this region that few areas are occupied by stable, mature vegetation. For example, the southern boundary of the Forest-Tundra zone as shown is almost certainly considerably farther south than the southern boundary of the "potential" forest tundra. Therefore, the zone boundaries have been adjusted according to the author's knowledge of the area, which procedure has made them rather subjective. This is undesirable but perhaps unavoidable at present. Probably both actual and potential vegetation should be mapped, if enough were known about the relationships of the two.

The zones of vegetation

The area is occupied by two physiographic regions, the continental part of the Hudson Bay Lowlands and the Canadian Shield (Fig. 2). The zones of vegetation found in each are treated separately, since it is likely that the distinctive nature of the vegetation of the Hudson Bay Lowlands is controlled primarily by the physiography of the region. This primary division of vegetation zones accords with the views of Hustich (1957) but it may prove to be invalid after further work. In this context the term vegetation zones describes a geographical region occupied by a number of plant communities and characterized *either* by the prevalence of one *or* by a particular proportion of two or more communities.

Within the physiographic regions there are zones of vegetation whose limits have been ascertained by the methods described above. In the shield

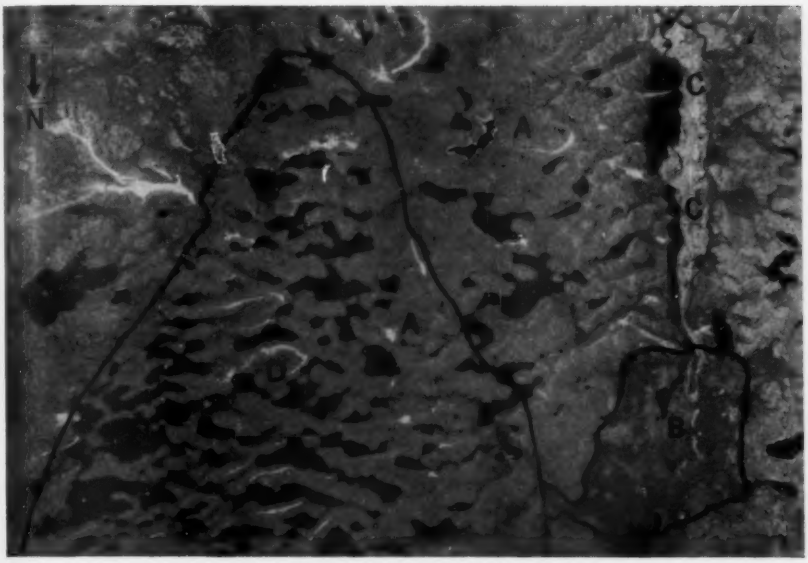


Fig. 3. Vertical air photograph A 14678-130 (scale 1:60,000) showing an area of Tundra northeast of Caribou Lake. The vegetation on the uplands is a heath tundra (A) with scrub spruce in depressions and along watercourses (B). Conspicuous landforms are the esker (C) and the area of washboard moraine (D, outlined). (This illustration and those following are parts of R.C.A.F. photographs; their publication here has been authorized).

region the zones are divided primarily on the basis of physiognomic criteria into Tundra, Forest-Tundra, Open Coniferous Forest, and Closed Coniferous Forest. In the lowlands, the zones are defined by the physiognomy of the vegetation and the surface pattern of the land.

In the following paragraphs the vegetation, physiography, and photographic appearance of each zone will be described. Under photographic appearance are included the tone, texture, and structure that can be detected by stereoscopic examination of vertical air photographs. The designations of tone have been determined with the Munsell Color Chart. The absolute achromatic tones are used with the Munsell notations, as follows: white (N8 - N9); light grey (N7); grey (N5 - N6); dark grey (N4); very dark grey (N3); and black (N1 - N2). They are provided as additional guiding information, but it is clear that the varying quality of the negatives and prints precludes any general application of tone criteria in interpretation.

1. Canadian Shield region

(a) Tundra (Fig. 3)

The summits and upper slopes of ridges are occupied by a community dominated by ericoid shrubs and fruticose lichens. The chief species (no

detailed descriptions of the vegetation are given in this paper. They can be found in the references listed, others will be published later) are *Vaccinium uliginosum, V. vitis-idaea* ssp. *minor, Empetrum hermaphroditum, Loiseleuria procumbens, Arctostaphylos alpina,* with *Cladonia rangiferina, C. rangiformis, C. mitis, Cetraria nivalis,* and *C. islandica.* Locally *Diapensia lapponica, Phyllodoce caerulea,* and *Rhododendron lapponicum* form distinct associations. Lower slopes and river banks bear phanerophytic vegetation, dominated by *Salix* species (chiefly *S. planifolia), Betula glandulosa,* and *Alnus crispa.* Poorly drained areas are occupied by thin wet peat, bearing communities dominated by *Eriophorum spissum, Scirpus caespitosus* ssp. *austriacus, Carex rotundata, C. paupercula,* and *C. stans.* Elsewhere, deeper and drier peats have *Sphagnum* ssp. with *Andromeda polifolia, Rubus chamaemorus, Vaccinium uliginosum,* and *Ledum decumbens.* Along rivers, on alluvial soils and esker slopes groups of *Picea glauca* are common, suggesting that the almost complete absence of trees is not controlled directly by the climate.

The area has considerable relief inland, with extensive morainic ridges (local areas of washboard or minor moraine are found), eskers, raised beaches, and occasional ridges of outcropping bedrock. On the photographs, tundra heaths are light grey to grey (N6 - N7) in tone, shrub communities are grey (N5), cottongrass-sedge bogs are light grey to white (N8), and the bare sand of eskers and beaches is white (N9). The heaths and shrub areas lack structure and texture. Bog vegetation is flat, but often shows large polygons.

(b) Forest-Tundra (Fig. 4)

Field studies in this region (Ritchie, 1959) have shown that to a certain extent man has influenced the nature of the vegetation. Forest fires and felling have removed many trees from upland sites and treeless heath prevails. However, there is evidence in certain areas that the tundra heath of dry ridges and summits is a stable type, so for the present the name "Forest-Tundra" is used. From the tundra zone in the northeast corner of the province to the areas of continuous forest at the southern limit of the Subarctic there is a gradual transition of vegetation and the boundaries shown in Fig. 2 are arbitrary.

The tundra of upland slopes is floristically and physiognomically similar to that of the Tundra zone. The chief species are *Vaccinium uliginosum, V. vitis-idaea* ssp. *minor, Loiseleuria procumbens, Empetrum hermaphroditum, Cladonia mitis, C. rangiferina,* and *Cetraria nivalis.*

On lower slopes there is a scrubby vegetation of depauperate *Picea mariana* with *Betula glandulosa.* In basins where drainage is slightly impeded shallow peats develop, bearing stands of small trees of black spruce, with the ground vegetation dominated by *Ledum groenlandicum, Sphagnum* ssp., *Vaccinium vitis-idea* ssp. *minor, and Rubus chamaemorus.* In areas of poorer drainage, tracts of treeless vegetation prevail, with mainly *Eriophorum spissum, Carex stans, C. capitata, C. rariflora,* and *Scirpus caespitosus.*

Alluvial substrata and eskers bear stands of white spruce, closed on moist sites and open on the drier sites, usually on eskers. The trees in the alluvial deposits often show excellent growth, a height of 20 m. and 36 cm. d.b.h. at 120 years being typical. There is a characteristic sequence of vegetation from younger to older alluvial deposits, and it seems likely that this change is seral (successional) as well as spatial. The zones vary from a sedge-grass pioneer community through zones of shrub (*Betula glandulosa* and *Salix* ssp.), invading trees of *Larix laricina* and *Picea glauca*, to a pure stand of white spruce with a herb-moss ground layer and a few tall shrubs. Older sites, where deep peat has accumulated, show evidence of a replacement of white spruce by black spruce.

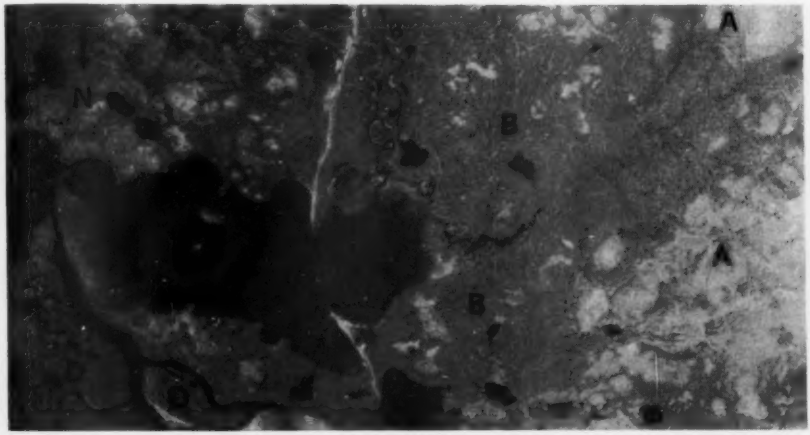


Fig. 4. Vertical air photograph A 14678-126 (scale 1:60,000) showing an area of Forest Tundra at Caribou Lake. Visible are tundra (A), scrub spruce forest (B), and alluvial deposits bearing a complex of pioneer and stable closed forest types (D).

In the Forest-Tundra zone and in the Open Coniferous Forest zone are numerous thick deposits of stratified peat that occur often as residual mantles on islands and lake shores and show conspicuous vertical faces 2 to 5 m. high, where the peat is being eroded slowly. Detailed descriptions of them are found in other reports, (Ritchie 1959). Their surface is covered with tundra vegetation, a heath tundra on dry deposits and a sedge-cotton grass tundra on wetter sites. Often they show large polygonal fissures.

Physiographically this area differs from the Tundra zone only in the greater number of large eskers, and the smaller amounts, especially inland, of marine sediments and beach material.

On the photographs the following range of tones is found: tundra heaths — light grey (N7); scrubby black spruce forest — dark grey to very dark grey (N5 - N4); birch and willow scrub — grey (N6); sedge-cotton grass

tundra — light grey (N5); esker and beach sands — white (N8). Upland heath and birch-willow scrub are textureless and structureless, and can be distinguished only by colour and by assuming that their physiographic positions are consistent. Black spruce muskeg shows only slight stippling under the stereoscope. White spruce stands on alluvium show the same tone as black spruce on peat, but are readily distinguished by the medium stippling and the conspicuous tall spires of the trees that often form a regular palisade along the banks of channels and oxbows. Deep peats with tundra are characterised by polygon patterns and the prevalence of small lakes and ponds.

(c) Open Coniferous Forest (Fig. 5)

The main feature of this zone is the prevalence on upland sites of stands of well-spaced conifers, with a ground vegetation consisting of two components — a mat of lichens, closely associated with low prostrate shrubs (*Vaccinium vitis-idaea* ssp. *minor* and *Empetrum hermaphroditum*) and a discontinuous stratum of medium shrubs (chiefly *Betula glandulosa, Salix myrtillifolia,* and *S. arctica*). *Picea mariana* (black spruce) is the commoner of the spruces, forming the tree layer on drift ridges and hills. On eskers and floodplains *P. glauca* (white spruce) replaces black spruce. Trees of black spruce about 200 years old seldom exceed 9 m. in height and 15 m. d.b.h. Many show extensive reproduction by layering. On esker slopes along streams white spruce trees 18 m. high and 70 cm. d.b.h. at 200 years of age have been observed in this zone.

Poorly drained sites are occupied by muskeg and bog vegetation, and in many areas deep residual peats are common (described in detail in Ritchie 1959, pp.28-31) In this zone and in the Tundra and Forest-Tundra, fens are rare.

In Northern Manitoba the nature and extent of open coniferous forests appear to differ markedly from those described by other workers from regions east of Hudson Bay. There the open coniferous region (the lichen woodland of Hare and Taylor 1956) appears to have extensive areas of *Picea-Cladonia* forest, with the *Cladonia* layer deep and well developed. In many areas of Northern Manitoba mesic sites within this zone are occupied by secondary communities as a result of extensive fires. It has been found, in an admittedly small sample of areas, that the deep *Cladonia* carpet is often absent and replaced by a sparser lichen mat with prostrate shrubs, where the lichen *Stereocaulon* appears in greater abundance than species of *Cladonia*. Following the experience of Scandinavian workers it has been suggested (Ritchie 1959, p.37) that this shift in lichen dominance may sometimes be due to overgrazing by Barren Ground caribou. The importance of the vegetation of the Forest Tundra and Open Coniferous Forest zones in studies of the ecology of the Barren Ground caribou is clear from the work of Banfield (1954), and Darling and Leopold (1954). At this stage it can be said with certainty only that in these zones the proportion of mesic sites occupied by stable or mature

vegetation is remarkably small — as little as 5 per cent in areas that the writer has examined, although this figure is probably lower than the average. If it was established with certainty that the vegetation found in undisturbed sites of Forest-Tundra and Open Coniferous Forest areas is essential for these animals as winter range, then the apparent impoverishment of vegetation by fire, together with slow recovery, might well be an important factor in their ecology. To what extent it is responsible for the well-established diminution of herds is not clear, but it is a field of inquiry that deserves close attention (cf. Darling and Leopold).

On the photographs the Open Coniferous Forest presents a characteristic appearance. The spire-shaped spruces can be seen easily under a magnifying stereoscope; they form a coarse stippling of dark grey (N4) on a ground vegetation background of smooth, light grey (N7 or 6) appearance. Patches of bog and muskeg are readily recognized by the criteria given under Forest-Tundra.

Throughout the zone there is considerable relief with ridges and undulating hills of drift, large eskers, and local drumlin fields.

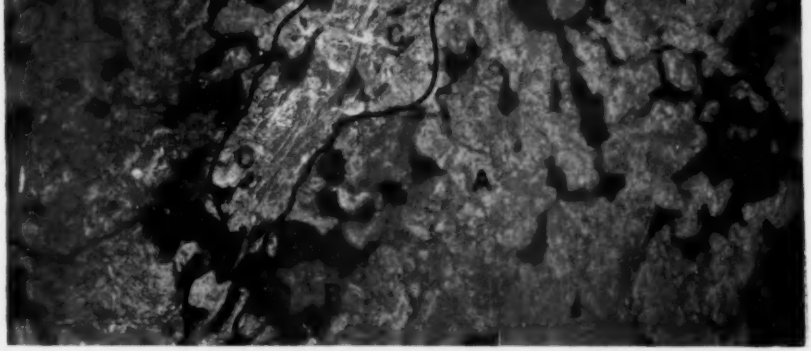


Fig. 5. Vertical air photograph A 15707-74 (scale 1:60,000) showing an area of Open Coniferous Forest in the northwest corner of the province. Areas outlined are glacial drift with open spruce-lichen forest (A), peat-filled depressions with moss muskeg (B), and an esker ridge and apron with open spruce-lichen forest (C).

(d) Closed Coniferous Forest (Fig. 6)

This zone can be divided into approximately equal western and eastern areas which are, however, not shown on the map (Fig. 2). They are separated on the basis of a difference in the proportion of poorly drained, predominantly peat-covered land to forested upland areas. In the western section the area occupied by bogs and muskegs is not greater than 50 per cent of the total

area, whereas in the eastern part it comprises 50 to 80 per cent. The western area shows a prevalence of closed-crown forests on mesic sites, and the few areas that show no recent disturbance by fire bear a closed stand of *Picea mariana* with a thick carpet of weft- and tuft-form mosses as the only subsidiary layer. After fire various seral types are found, and *Pinus banksiana* (jackpine) and *Betula papyrifera* (white birch) are the chief tree species to follow pioneer shrub stages. These subseral details have been described elsewhere (Ritchie 1956). Rock ridges, eskers, and sandplains bear stands of jackpine, and peats are covered by muskeg and treeless bog. A part of this zone that is judged to be representative of the whole has been mapped in detail (Ritchie 1958).

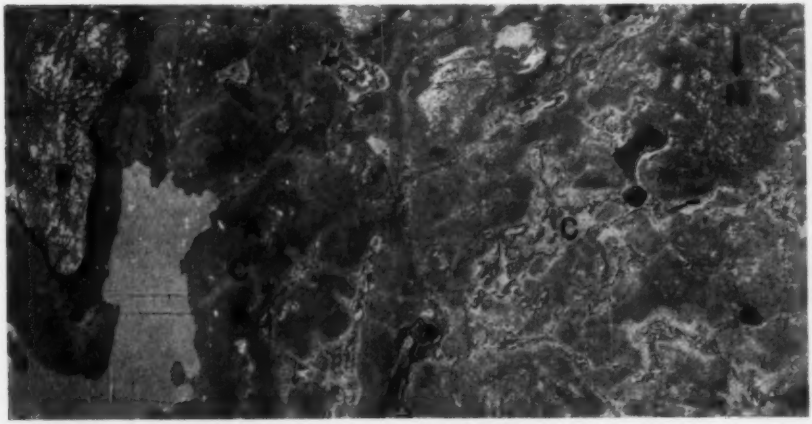


Fig. 6. Vertical air photograph A 14889-133 (scale 1:60,000) showing an area of Closed Coniferous Forest at McBride Lake. Upland types shown are closed forest (A), here dominated by spruce with occasional birch; and an open jackpine community on outcropping bedrock (B). Depressions are occupied by bog complexes (C).

The western section of the zone shows marked physiographic differences from the eastern. In the west relief is considerable, with ridges of bedrock becoming more numerous towards the Saskatchewan boundary and drift ridges, sandplains, and eskers common everywhere. The eastern part is gently rolling and has extensive shallow basins occupied by lakes and large tracts of peat covering the drift. Shallow lacustrine deposits are common here and were apparently formed by the northern extension of Glacial Lake Agassiz (Glacial Map of Canada, 1958).

A detailed account of the photographic characteristics of this zone has been published (Ritchie 1958). It is sufficient here to point out that the diagnostic cover type, the closed-crown coniferous forest on upland sites, is readily recognized by its dark grey tone (N4) and even stippling.

2. Hudson Bay Lowlands

Two general facts about the tentative categories of the vegetation zones of the Hudson Bay Lowlands have emerged from an examination of the area on the ground, from the air, and by inspection of air photographs: (a) that one can recognize on floristic and structural grounds certain categories of vegetation that occupy large, often discontinuous tracts of the lowlands; (b) that these types recur with floristic and structural consistency. They are tabulated and listed below with a brief explanation of their main features. Clearly, these eleven categories are not all of comparable rank, whether one considers them from seral or static points of view, and they are put forward here merely as a first step. Subsequent work will certainly expand and refine the list, not only by recognizing smaller groups within the present ones, but by presenting quantitative data to illustrate the degree of constancy of the various groups. (A forthcoming paper on the vegetation of the lower Hayes River area will make available detailed descriptions of many of these types). Further work will also permit clarification of the status of the groups in terms of both seral and static features, so that they can be arranged in a valid hierarchy. Much work is required before this will be possible, but investigation is proceeding along lines that will make possible classification in terms of dynamic and static attributes.

The following table sets out this preliminary, highly tentative separation.

Substratum	*Vegetation type*		*Community type*
Primarily peat*	Bog	with trees	Moss Muskeg
			Lichen Muskeg
		without trees	Palsa Bog
			String Bog
			Heath Bog
	Fen		Larch Fen
			Dwarf Birch-Sedge Fen
Primarily mineral	Marsh		Sedge-Grass-Herb Meadow
	Scrub		Dwarf Birch-Willow
	Forest		Balsam Poplar Forest
			White Spruce Forest

*This division of the vegetation on peat is tentative, but an attempt has been made to align it with the classical approach of Cajander (1913), which has been adopted widely in Europe (e.g. Sjörs 1948, Tansley 1952).

The following provides brief general descriptions of the above community types.

Moss Muskeg. — This is the type that has been referred to in earlier publications simply as "muskeg" (Hustich 1949; Ritchie 1956, 1959). The characteristics are: an open stand of depauperate *Picea mariana* on acid peat; the ground vegetation dominated by mosses, often forming hummocks (chiefly *Sphagnum fuscum, S. warnstorfianum, Aulacomnium palustre);* a low shrub stratum of *Ledum groenlandicum* with other ericoid shrubs, and a sparse medium shrub stratum of *Salix* species and *Betula glandulosa.*

Lichen Muskeg. — This type bears close physiognomic resemblances to Moss Muskeg, differing in the replacement of the moss carpet by a lichen cover, dominated by *Cladonia rangiferina* and *C. alpestris.* The *Ledum* element is present and covers only slightly less of the ground than the lichens, being associated with small amounts of other low shrubs *(Vaccinium uliginosum, V. vitis-idaea* ssp. *minor,* and *Empetrum hermaphroditum).* Vegetation of this type is common in the lowlands along drainage channels on levees, and as raised islands in vast areas of Larch Fen and Bog.

Palsa Bog. — Palsas are small mounds of peat with cores of permafrost, capped by a *Ledum-Sphagnum-Carex* community, with scattered black spruce trees locally. This type forms large complexes, with wet sedge peat or open water between individual palsas.

String Bog. — This consists of parallel ridges of peat that are raised 0.5 to 2.0 m. above the level of the surrounding water or bog, and that usually run parallel to the contours. The ridges bear a shrub, or locally a larch community, with the surface cover made up of *Sphagnum* hummocks, *Carex* sp., and small ericaceous shrubs *(Andromeda, Ledum, Vaccinium vitis-idaea* ssp. *minor).* The intervening areas are often covered with open, shallow water or *Carex* and *Drepanocladus-Calliergon* communities.

Heath Bog. — This term is given to extensive tracts of more or less treeless vegetation on deep (1 m.) peats, found especially in the northern part of the area. The vegetation is dominated by *Ledum groenlandicum, L. decumbens,* and *Empetrum hermaphroditum* associated with *Cladonia alpestris, C. mitis* and species of *Sphagnum.*

Larch Fen. — This develops on wet, shallow peats, where there is some influence near the surface from the mineral substratum. The peat is neutral or slightly basic. Depauperate, widely spaced trees of *Larix laricina* dominate and there is a dense shrub layer of *Betula glandulosa, Salix pedicellaris* var. *hypoglauca.* The ground vegetation is a moss-sedge-prostrate shrub complex, with *Tomenthypnum nitens, Drepanocladus* spp., *Campylium stellatum, Carex chordorrhiza, C. tenuiflora, C. diandra, Eriophorum viridi-carinatum* as the main species and a rich herb component.

Dwarf Birch-Sedge-Fen. — This is very similar in composition to the Larch Fen, and the main difference is the absence of larch.

Sedge-Grass-Herb-Meadow. — This is a marsh type, often salt marsh and found on tidal flats at the coast and estuaries. It has been previously described (Scoggan 1951) as tundra or barren extending down the western shore of Hudson Bay. It is primarily the plant cover of recent alluvial or marine deposits, marshy in character, and dominated by *Carex (C. stans, C.*

paleacea, C. aquatilis), grasses *(Dupontia fisheri, Puccinellia distans, Colpodium fulvum), Triglochin maritima,* and a rich herb component *(Primula egaliksensis, Parnassia multiseta, Lomatogonium rotatum* etc.). It is a seral type, being invaded by Dwarf Birch-Willow, Balsam Poplar Forest, and White Spruce Forest.

Dwarf Birch-Willow. — Large tracts of land adjacent to marsh flats, and on river islands and shorelines are occupied by dense shrubby vegetation. The chief species are willows *(Salix brachycarpa, S. cordifolia,* and *S. rigida)* and dwarf birch *(Betula glandulosa).*

Poplar Forest. — On some older alluvial and beach deposits dense stands of *Populus balsamifera* with a sparse ground cover of herbs are common. In many places young trees of *Picea glauca* are invading these stands.

White Spruce Forest. — On other old alluvial deposits excellent stands of white spruce are found. They are pure, with sparse subsidiary shrub strata. The ground vegetation is either a predominantly herbaceous community (chief species *Cornus canadensis, Linnaea borealis* ssp. *americana, Mitella nuda, Geocaulon lividum, Pyrola secunda)* or a predominantly moss-dwarf shrub community *(Hylocomium splendens, Pleurozium schreberi, Salix myrtillifolia, Vaccinium vitis-idaea* ssp. *minor, Arctostaphylos rubra).*

The main vegetation zones of the Hudson Bay Lowlands are the following (see Fig. 1).

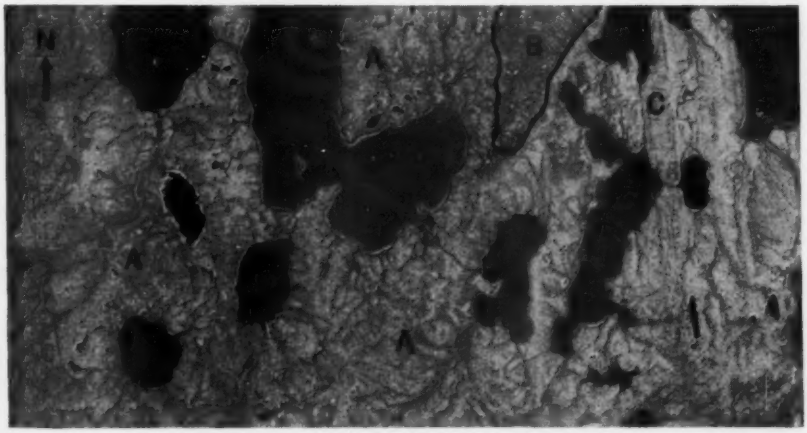


Fig. 7. Vertical air photograph A 14977-123 (scale 1:60,000) showing an area of Transitional Type between the Hudson Bay Lowlands proper and the Canadian Shield. Most of the area has only slight relief with extensive moss muskeg (A). Upland sites bear open coniferous forest (B) and (C), the latter growing on a raised beach.

(a) Transition Type (Fig. 7)

This forms the boundary zone between the Canadian Shield and the Hudson Bay Lowlands in Manitoba and is transitional, both in vegetation

and physiography. The vegetation in the southern two-thirds of the area is predominantly a Moss Muskeg community on deep peat, whereas in the north there are extensive peats without trees and with conspicuous polygon features (the latter are the Heath Bogs). The muskeg vegetation has been described above. Occasional upland features, such as drift hills, beaches, or drumlins are occupied by either open spruce-lichen forests or closed spruce-feather moss forests. In the wetter sites there are Treeless Bogs, often of the String-Bog Type.

Relief is poor and shows only slight undulations. Dendritic drainage patterns prevail locally, and many areas have large numbers of small lakes.

On the photographs, the predominant muskeg type is grey to dark grey (N5 to N4) and has faint stippling, with the individual trees just visible under the magnifying stereoscope. A marked increase in the height of black spruce is seen along drainage channels. On upland sites, Open Coniferous and Closed Coniferous Forests can be distinguished by the criteria given above.

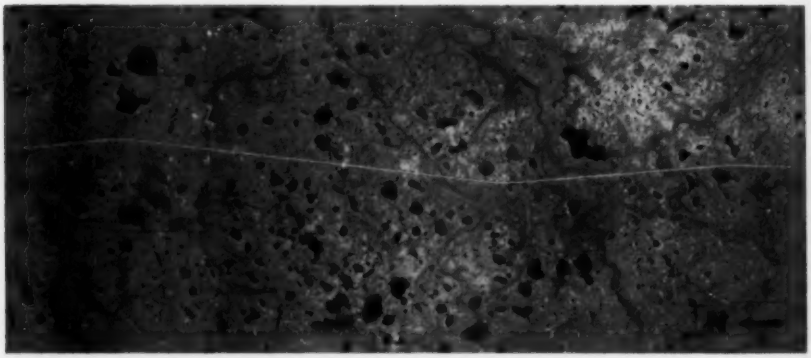


Fig. 8. Vertical air photograph A 14126-15 (scale 1:60,000) showing an area along the Hudson Bay Railway at about 57°50′N. occupied by Moss Muskeg. The land is almost entirely covered with a mantle of peat bearing moss muskeg and shows slight ponding and dendritic drainage patterns, which are characteristic of the entire zone.

(b) Moss-Muskeg Type (Fig. 8)

This zone occurs only in the Hudson Bay Lowlands proper and the characteristic vegetation is the Moss-Muskeg community on deep (60 - 200 cm.) peat. Along the watercourses there are dense stands of shrubs *(Salix planifolia, Betula glandulosa, Alnus rugosa* ssp. *americana)* and occasional small stands of conifers *(Picea glauca* and *Larix laricina)* on alluvial substrata.

The terrain is flat, with extensive dendritic drainage patterns and moderate local ponding. The only relief is provided by a few raised beaches and gravel bars. In places large areas of peat are arranged in slight, irregular mounds.

On the photographs, the gross features are the dendritic drainage patterns, moderate ponding and irregular, crenate peat deposits, usually about

100 - 500 m. in diameter. The main vegetation type (Moss-Muskeg) is grey (N5) and light grey (N6) where the spruces are sparse.

(c) Treeless Bog Type (Fig. 9)

This zone occupies a northern and central position in the Hudson Bay Lowlands, and is characterized by the prevalence of treeless vegetation on peat. It is a region of excessively poor drainage, with abundant ponds, many small lakes, and wet bogs. There are two main types of plant cover: a) fragmentary Moss-Muskeg with depauperate trees of *Picea mariana;* b) Treeless Bog, the most common type in this zone, dominated by heath vegetation and sedge-cotton grass vegetation, the latter in wetter sites. Large polygon patterns are common in this zone. Only along streams and rivers is there any fair tree growth, and here stands of *Picea glauca* and *Larix laricina* are found on mineral soil.

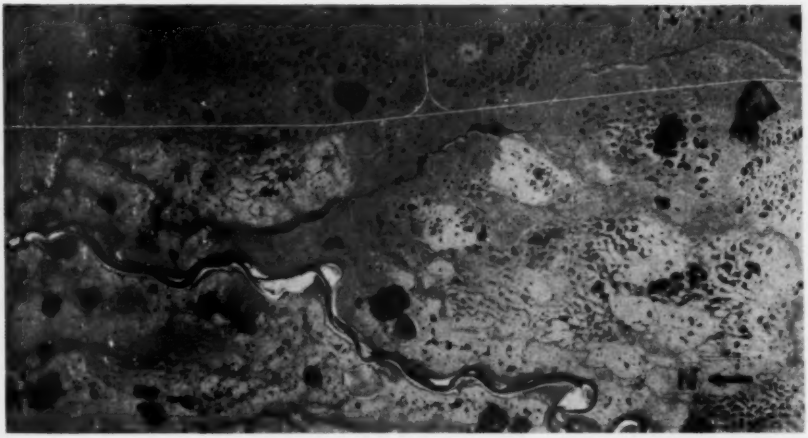


Fig. 9. Vertical air photograph A 14126-2 (scale 1:60,000) showing the characteristic excessively ponded, poorly drained nature of the land in the Treeless Bog zone near 58°10'N. on the Hudson Bay Railway. Tree growth is confined to the main water courses. Palsa bog occurs occasionally (P), and the extensive polygon patterns on the bog surface are just visible in the areas between the two main streams.

Only gravel and sand deposits provide any relief in this zone and drainage patterns are immature or lacking. The surface is characterized by innumerable shallow ponds and lakes, with local development of Palsa Bog. Permafrost is present in many of the drier peat deposits, with the active layer 30 - 50 cm. in depth.

On the photographs, the excessive ponding, occasional Palsa Bogs and the fine reticulate pattern of the peat polygons are characteristic. The heath tundra is grey to light grey (N6 to N7), the treeless sedge-cotton grass bogs are light grey to white (N7 to N8), and the shrub and tree vegetation along

watercourses is grey (N5). In this last type individual trees can often be made out under the stereoscope.

(d) Lowland Complex (Fig. 10)

Within the area of the Hudson Bay Lowlands mapped in Fig. 1 as "Lowland Complex", there are several distinct and important vegetation types. However, none of them occupies continuous areas large enough to make possible more detailed mapping at this scale. (These subdivisions will be mapped separately in the 1: 500,000 maps of this region). The types of vegetation included in this complex are as follows, using the terms described above:

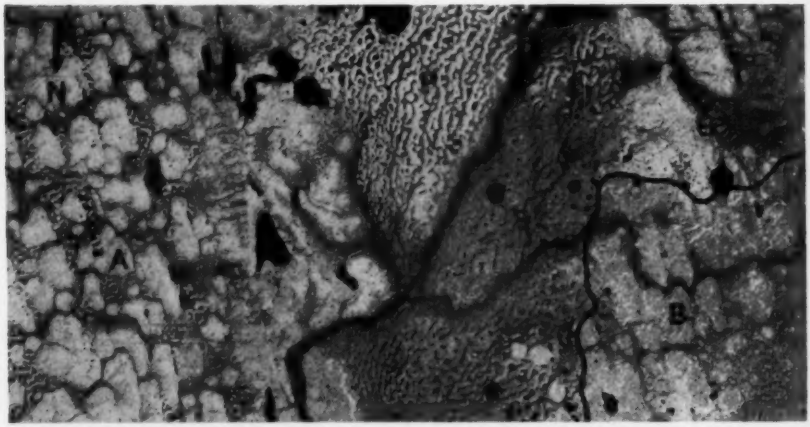


Fig. 10. Vertical air photograph A 14219-86 (scale 1:60,000) in the Hudson Bay Lowland Complex zone near York Factory on the Lower Hayes River. Three types are shown here: extensive tracts of lichen muskeg on weathered beaches (A), areas of shrub that have replaced lichen muskeg after fire (B), and palsa bogs in poorly drained regions (P).

Moss Muskeg, Lichen Muskeg, Palsa Bog, String Bog, Larch and Scrub Fen, Sedge-Grass-Herb-Meadow, Treeless Bog, Balsam Poplar Forest, and White Spruce Forest. In general, older parts of this zone, usually farther inland, are covered with a mantle of poorly drained peat whose depth seldom exceeds 1 m. Often on levees along watercourses and as isolated raised islands in continuous areas of wet bog or fen is to be found one of the most striking types of vegetation. This is the Lichen Muskeg type that covers large areas in Fig. 10. Wetter parts of these older deposits bear Treeless Bog or Fen and the exact nature of the vegetation apparently depends on the depth of the peat, the movement of water in the peat or both. Where there is lateral movement of water carrying mineral nutrients neutral or basic peat is formed with a distinctive fen vegetation. Where there is no influx of mineral material, either directly or in minerotrophic water the peat is acid and bears a bog vegetation. On river banks, islands, and young beaches are zones of shrub

and tree vegetation, the former dominated by *Salix planifolia, S. rigida,* and *Betula glandulosa,* the latter by *Picea glauca* and *Populus balsamifera.* Fig. 11, showing part of the delta of the Knife Rivers, where estuary deposits of calcareous alluvium are found, illustrates this type. On the older alluvial sites excellent stands of white spruce are found.

Extensive flats are being exposed along the coastline as the land rises. They are occupied by marsh vegetation and later invaded by shrubs. In older, usually slightly better drained sites a tree zone occurs that is dominated by *Picea glauca,* with *Populus balsamifera* in the southern parts of the Hudson Bay Lowlands.

The entire zone is poorly drained and the interfluves are occupied by bogs. The few rivers have steep banks that are cut into the marine clays, and many of the tributaries meander extensively. Slight relief is provided by beaches, bars, and spits, and at Churchill there is a unique outcrop of bedrock.

On the photographs gross patterns, the result of both the appearance of the vegetation and of physiographic processes, are easily recognized. The following table summarizes the main characteristics of the vegetation, as seen under a magnifying stereoscope.

Vegetation type	*Tone*	*Texture and appearance*
Lichen Muskeg	light grey to white (N7 - N8)	Large, crenate mounds or continuous tracts along watercourses and beaches, the trees are denser at the margins; the individual trees are depauperate, but can be seen clearly under X 4 magnification.
Treeless Bog	grey to white (N6 - N8)	Flat and treeless; Palsa and String Bogs have characteristic patterns (Fig. 9).
Fen	dark grey to grey (N5 - N6)	Flat, lacking pattern, but often with many small elongate ponds (flarks); the diffuse effect of fens with trees (larch) is visible.
White Spruce Forest	grey (N6)	Individual spire-shaped trees clearly visible, the closed-crown stands making a coarse stippling.
Balsam Poplar Forest	grey to dark grey (N6 - N7)	Diffuse, fluffy appearance of crowns, individual trees not visible; slightly irregular surface texture.
Marsh	light grey (N7)	Flat, textureless, and structureless.
Shrub	grey to light grey (N6)	Flat, textureless, and structureless.

Fig. 11. Vertical air photograph A 11022-244 (scale 1:60,000) near the mouth of Knife River. Two main categories of vegetation are shown: extensive stands of Closed White Spruce Forest on recent alluvium (A), and an area of island-like mounds of peat (B), surrounded by continuous fen and bog vegetation. The peat "islands" show a peripheral zone of moss muskeg and a central zone of lichen muskeg (or tundra in some areas).

Concluding Comment

Although the exact position of the boundaries will be changed as more detailed mapping at a larger scale proceeds, the general configuration of the zones will probably retain validity. Furthermore, whereas later field work will make possible a more detailed subdivision of the categories, particularly on the Hudson Bay Lowlands, it is likely that the account given here provides a balanced view of the chorology of the vegetation in the region. The lines along which this work will be pursued in future are (a) extension of the detailed descriptive studies of particular areas, (b) exploration of the possibilities of correlating the major zones of vegetation with boundaries between environmental regions, and (c) continuation of a detailed survey of the literature on the vegetation of the subartic zone in all parts of the Northern Hemisphere.

These investigation have been supported generously by the National Research Council of Canada, the Arctic Institute of North America, and the University of Manitoba.

References

Banfield, A. W. F. 1954. Preliminary investigations of the Barren Ground caribou. I and II. Wildlife. Bull., Ser. 1, 10 A, pp. 1-79, 10 B, pp. 1-112.

Beckel, D. K. B. 1958. A pilot study of caribou winter range, Brochet, Manitoba, by means of airphoto analysis and interpretation. Can. Wildlife Serv., (unpublished).

Cajander, A. K. 1913. Studien über die Moore Finnlands. Acta for. fenn. 2, No. 3, 208 pp.

Cheney, T. A., and D. K. Brown Beckel. 1955. Fort Churchill environmental analysis. Cornell Univ., Ithaca N.Y., 349 pp. (unpublished).

Coombs, D. B. 1954. The physiographic subdivisions of the Hudson Bay Lowlands south of 60 degrees north. Geog. Bull. 6:571-85.

Glacial Map of Canada, 1958. Published by Geol. Assoc. of Can.

Hare, F. K. 1955. Mapping of physiography and vegetation in Labrador-Ungava, a review of reconnaissance methods. Can. Geog. 5:17-28.

———— 1959. A photo-reconnaissance survey of Labrador-Ungava. Dept. of Mines and Technical Surveys, Geographical Branch, Ottawa. Mem. 6, 83 pp.

Hare, F. K., and R. G. Taylor. 1956. The position of certain forest boundaries in southern Labrador-Ungava. Geog. Bull. 8:51-73.

Hustich, I. 1949. On the forest geography of the Labrador Peninsula Acta Geog. 10, No. 2, 63 pp.

———— 1957. On the phytogeography of the Hudson Bay Lowland. Acta Geog. 16, No. 1, 48 pp.

Radforth, N. W. 1952. A suggested classification of muskeg for the engineer. Nat. Res. Coun. Can. Tech. Mem. No. 24.

———— 1958. Organic terrain organization from the air. Handbook No. 2, Def. Res. Bd., Rep. No. D.R. 124, 23 pp.

Ritchie, J. C. 1956-59. The vegetation of northern Manitoba. I. Can. J. Bot. 34:523-61; II. Ecology 38:429-35; III. Tech. Pap. No. 3, Arct. Inst. of N. Am., 56 pp.; IV. The Caribou River area. Can. J. Bot. 38:185-99.

———— 1958. A vegetation map from the southern Spruce Zone of Manitoba. Geog. Bull. 12:39-46.

Scoggan, H. J. 1957. Flora of Manitoba. Nat. Mus. Can., Bull. 140, 610 pp.

Sjörs, H. 1948. Myrvegetation i Bergslagen. Acta phytogeog. suecica 21, 299 pp.

———— 1958. Bogs and fens in the Hudson Bay Lowlands. Arctic 12:3-19.

Tansley, A. G. 1950. The British Isles and their Vegetation. London. Cambridge University Press, 930 pp.

TYPE E BOTULISM: A HAZARD OF THE NORTH

Claude E. Dolman*

In 1908, on returning after two years' absence to the head of the Mackenzie Delta, the explorer Stefansson (1929) learned that many of his Eskimo acquaintances were dead, including a group of eight "poisoned by eating the meat of a freshly killed white whale." Calamities of that sort were familiar to whalers and attributed by them to ptomaine poisoning; but Stefansson concluded this could scarcely be the cause, as he had seen tons of semi-decayed whale meat eaten without harm. He appears to have been the first to suggest that these mysterious fatalities might be due to trichinosis (Stefansson 1914).

Twenty years later, Parnell (1934) also referred to "deaths of whole families which are periodically reported among the Eskimos." These were "always ascribed to 'ptomaine poisoning': without, however, any real evidence." Apparently unaware of Stefansson's prediction, Parnell speculated that the "Trichina worm", whose presence he had noted in arctic foxes and polar bears in the eastern Canadian Arctic, could be responsible for such deaths. These conjectures were later rendered plausible by parasite surveys of the fauna conducted by Thorborg *et al.* (1948) in Western Greenland, by Brown *et al.* (1949) in the Northwest Territories, and by Brandly and Rausch (1950) in Alaska, which established that *Trichinella spiralis* has a holarctic distribution. Connell (1949), in his review of the problem, indicates that the sled dog, and also certain wild carnivores, particularly the polar bear and the arctic fox, are liable to be infested; and that occasionally such marine mammals as the white whale (beluga), the walrus, and the bearded seal, somehow become hosts to *Trichinella*. There is now plenty of evidence that human trichinosis can occur in the Far North through consumption of the raw or inadequately cooked flesh of many of the above species.

Without minimizing the seriousness of this risk of trichinosis, the present report draws attention to botulism as the probable explanation of many of the outbreaks of fatal poisonings to which Stefansson and Parnell referred. As the food habits of the natives of certain arctic and subarctic

*Dept. of Bacteriology and Immunology, Univ. of British Columbia, Vancouver, B.C. and Connaught Medical Research Laboratories, Univ. of Toronto (Western Division).

regions are very conducive to botulism, its control is mainly a problem of education in public health. Among Eskimos, the implicated foods have been raw or preserved products of marine mammals, particularly the white whale and seal; whereas raw salmon eggs prepared in various insanitary ways have caused several outbreaks among the Indians of the northern Pacific Coast. Enough of these occurrences have now been investigated bacteriologically to justify the claim that type E botulism is especially liable to be involved.

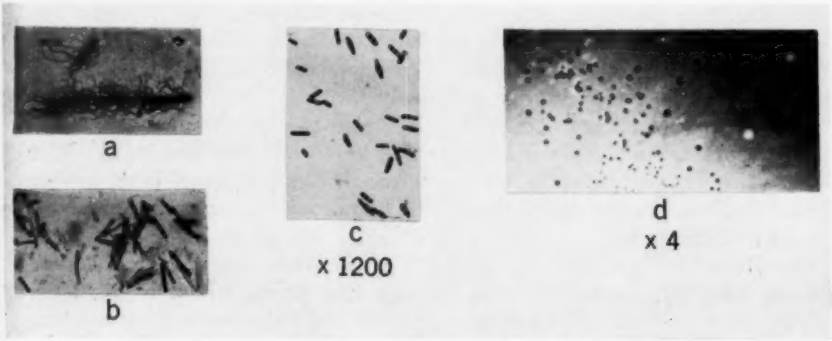


Fig. 1. *Clostridium botulinum* type E isolated from Alaskan Eskimo outbreaks. (a), (b), and (c), from beluga flipper ("muktuk"), Point Hope, 1950. (d), from grey whale fluke, Scammon Bay, 1959.

a. Short-chained and individual bacilli stained to show numerous peritrichous flagella (x 1200).

b. Toxic culture, Gram-stained, showing ghost forms, no spores (x 1200).

c. Atoxic, sporulating mutant culture (x 1200).

d. Mixed culture plated on blood agar and incubated anaerobically for 24 hours at 30°C. The minute, translucent type E colonies are surrounded by circular areas of haemolysis (x 4).

Definition, symptomatology and pathogenesis of type E botulism

Botulism may be defined as a serious and often fatal form of bacterial intoxication, affecting man and animals, which generally results from the ingestion of foodstuffs wherein *Clostridium botulinum,* a sporulating, anaerobic, motile bacillus has proliferated and produced a powerful neuroparalytic exotoxin (Fig. 1). There are at least 5 types of *Cl. botulinum,* designated alphabetically from A to E. They manufacture pharmacologically similar but immunologically distinct toxins, to which different animal species show varying degrees of susceptibility. Human botulism is nearly always due to type A, B or E.

Botulism and trichinosis are both endemic hazards of the Arctic, where the uncooked flesh of mammals may serve as vehicles for either disease; but they show few other resemblances. The two conditions differ importantly even in respect of the shared features. Trichinosis has a circumpolar distribution, whereas botulism has not been reported from Greenland or

from the far north of Scandinavia and Siberia. The largest recorded epidemic of arctic trichinosis, which occurred in West Greenland in 1947, was ascribed to walrus meat by Thorborg *et al.* (1948); but the possibility that dog flesh was actually to blame has been stressed recently by Fay (1960). In any event, sea mammals are seldom implicated in human outbreaks of this disease, whose most dangerous vehicle is apparently polar bear. By contrast, all known outbreaks of botulism in the Arctic have been attributed to food products of whales and seals, while type E botulism has never been traced to consumption of terrestrial carnivores.

The finer points of differential diagnosis between these diseases need not be considered here, but the following outline of their symptomatology and pathogenesis should enable even laymen to distinguish them. In trichinosis, the symptoms are extremely variable, because the larvae of *Tr. spiralis* may invade and become encysted in many tissues and organs, with a predilection for the musculature. However, two phases, intestinal and invasive, can generally be discerned. In the first week after infested meat has been swallowed, the encysted larvae are liberated into the bowel lumen, where most of them develop within a few days into mature adults. The viviparous females burrow into the intestinal mucosa, whence each emits some thousands of larvae. During this phase, which is often of 2 to 3 weeks duration, the main symptoms are abdominal — nausea, vomiting, diarrhoea, pain, and even intestinal haemorrhages, associated with fever — suggesting some form of gastroenteritis. Such troubles may be evanescent, or obscured by the early onset of symptoms referable to larval migration and invasion.

The young larvae find their way through the walls of intestinal lymphatics and veins, whence they are conveyed by the general circulation to all parts of the body, especially the skeletal muscles, diaphragm, and heart. In this phase, which usually lasts from the second to the sixth or seventh week of illness, prominent symptoms are muscle pains, swelling of face and eyelids, fever, and rash. In severe cases, stiffness of the trunk and limbs develop around the fifth week, followed sometimes by delirium, stupor, and coma as forerunners of death. The mortality rate in epidemics has ranged from 5 to 30 per cent. In the Greenland outbreak, about 300 persons were affected, and 33, or 11 per cent, died (Thorborg *et al*, 1948).

In botulism the incubation period is much shorter, usually 8 to 20 hours. Abdominal symptoms — nausea, vomiting, pain, and distension — may develop within a few hours after the meal, being followed generally by persistent constipation, and by the onset of a peculiar paralytic syndrome. When sufficient toxin has been absorbed from the stomach and intestines to reach sites adjacent to cranial and peripheral motor nerve endings, it exerts an inhibitory effect upon the mechanism of acetylcholine synthesis or release, thus interfering with the transmission of neural impulses to muscles and glands. Frequently, the cranial nerves supplying the muscles of the eye and throat are affected first, leading to dim, fuzzy, or double vision, loss of pupillary reflexes, and difficulty in swallowing or

speaking. This is accompanied or followed by generalized weakness, and in severe cases by respiratory and cardiac failure. Dryness of the mouth is often a troublesome feature. There is no rash, no fever, and consciousness is seldom impaired, even in the terminal stages. In fatal cases death generally ensues between the second and fifth days, but may occur as early as 20 to 24 hours, or as late as 10 to 14 days, after consumption of the botulogenic food. The fatality rates for type E botulism have ranged between 32 and 72 per cent in different parts of the world.

In 1932 an outbreak of botulism at Cooperstown, N.Y. (MacKenzie 1934), was eventually proved by Hazen (1938) to have been caused by one of the recently discovered type E cultures of *Cl. botulinum*. Including this first recognized type E episode, there have been to date at least 50 recorded occurrences in several countries, affecting 242 persons, of whom 85 died, a case fatality rate of 35.1 per cent. Table 1 shows that type E botulism has been confined mainly to Japan, Canada, and the United States, with single instances at Leningrad, U.S.S.R., in 1938, and at Frederiksberg, Denmark, in 1951. Excluding 3 outbreaks in the U.S.A. and a recent one in Canada attributed to imported foods, there remain 46 occurrences, all in northerly latitudes, in which fish, fish eggs, or marine mammals of local origin were invariably the vehicles. The exceptions are 2 episodes in the state of New York, due respectively to Labrador salmon and canned sprats from Germany; one in California attributed to mushrooms from Jugoslavia; and one in British Columbia due to salted herrings from Holland.

Table 1. Geographic distribution of type E botulism outbreaks.

Place of occurrence		*Outbreaks*	*Cases*	*Deaths*
JAPAN:	Hokkaido	19	137	39
	Northern Honshu	13	50	21
CANADA:	British Columbia	6	13	9
	Labrador	1	8	6
U.S.A.:	Alaska	6	18	6
	New York	2	6	2
	California	1	3	1
U.S.S.R.:	Leningrad	1	1	1
DENMARK:	Frederiksberg	1	6	0
	TOTALS	50	242	85

Overall case fatality rate, 35.1 per cent.

The chief factors governing these peculiar relationships have been analyzed and discussed in previous reports (Dolman and Chang 1953; Dolman 1957a, 1957b), and may be summarized as follows: (1) A relatively heavy dissemination of *Clostridium botulinum* type E spores in the soil, off-shore waters, and sea mud of certain regions in the Northern Hemisphere. (2) The liability of fish and sea mammals to ingest these spores while feeding, or to become contaminated with them at skin apertures and in wounds. (3) The capacity of the spores, after death of the host and under favourable temperature conditions, to vegetate, to migrate from the gut or

integuments into the muscles, and there to proliferate and manufacture toxin. (4) The unusually low thermal resistance of most type E spores, which precludes their survival in well-cooked foods. (5) The eating habits of the native populations of certain northern areas, who customarily consume marine products raw or only lightly cooked.

Epidemiology and geographic distribution of type E botulism outbreaks

The first and last of the foregoing factors mainly determine the regional distribution of type E botulism. The incidence will be high where both these prerequisites are present in full measure, as they are in parts of northern Japan and the British Columbian coast. A similar combination of circumstances presumably obtains in those areas of Alaska, the North-west Territories, and Labrador, where food habits of the Eskimos make botulism possible, and where the occurrence of outbreaks of type E botulism points to the probable existence of type E spores in these localities. In an attempt to verify this probability, it is planned to examine bacteriologically samples of sea-bottom mud and shore-line silt from the Canadian Arctic and Alaska.

Type E spores are evidently present also in certain parts of Europe, such as southern Russia, northern France, and Denmark, but seem to be more thinly scattered there than in the above areas.

Northern Japan

Japan was free of recorded botulism until 1951, since when there have been 32 type E outbreaks, all fish-borne, affecting 187 persons, of whom 60 died, a case fatality rate of 32.1 per cent. The areas of endemicity lie between latitudes 40° and 46°N. Hokkaido, the northernmost and least densely populated island (about 4 million inhabitants), has experienced 19 of these outbreaks, affecting 137 among 288 persons at risk, with 39 deaths (Nakamura *et al.* 1956; Iida *et al.* 1958; Iida, 1959, 1960). One outbreak was due to trout eggs, and the other 18 to home-made "izushi" — a relish made from raw fish, rice, and diced vegetables, pressed and fermented together in a wooden tub for periods ranging from a few days to 3 or 4 weeks. The fish most often used in the preparation of toxic "izushi" have been locally caught, bottom-feeding species, such a sole, carp, common goby, and sandfish; but in some outbreaks, predatory species such as horse-mackerel were implicated.

Since 1953, an adjacent area of northwestern Honshu has experienced at least 13 type E outbreaks, affecting 50 persons with 21 fatalities. Twelve of these were again due to "izushi", and one to canned mackerel. Apart from these proven outbreaks, Saito and Fujisawa (1956), and Yamamoto (1960) have traced 10 other "izushi"-borne outbreaks of botulism, involving 42 cases with 19 fatalities, which occurred within the same regions during the period 1930-52, but were not bacteriologically investigated.

Saito and Fujisawa (1956) and Nakamura *et al.* (1956) isolated type E cultures from intestinal samples of fish caught in the foregoing areas. They also found similar organisms in samples of coastal sand and of lake-shore and lake-bottom mud collected in vicinities where type E outbreaks had occurred. These observations suggest that the fish used for "izushi" could have become contaminated either by their intestinal flora when they were gutted and soaked in water, or through traumatic and telluric exposure after capture.

British Columbia, Yukon, and southeastern Alaska

Since 1940, on the other side of the northern Pacific Ocean, there have been at least 12 comparable outbreaks of botulism due to locally caught fish or their products. In another episode the implicated fish originated several thousands of miles away. Altogether, 25 persons were affected, of whom 18, or 72 per cent, died. (Table 2, Fig. 2).

Table 2. Fish-borne botulism outbreaks in British Columbia, Yukon and southeastern Alaska.

Place of occurrence	*Date of occurrence*	*Cases*	*Deaths*	*Foodstuff implicated*	*Type involved*
Nr. Whitehorse, Yukon	Aug. 1940	5	3	Salmon eggs	?
Nanaimo, B.C.	Sept. 1944	3	3	Home-canned salmon	E
Ketchikan, Alaska	Aug. 1948	2	1	Salmon eggs	?
Vancouver, B.C.	Oct. 1949	2	1	Home-pickled herring	E
Natal, B.C.	Sept. 1952	1	1	Home-pickled trout	E
Bella Bella, B.C.	Nov. 1954	3	1	Salmon egg "cheese"	E
Prince Rupert, B.C.	Aug. 1957	3	3	Chum salmon eggs	E
Port Edward, B.C.	July 1958	1	1	Spring salmon eggs	B
Hydaburg, Alaska	Aug. 1958	1	1	Salmon eggs	?
Hydaburg, Alaska	Sept. 1959	1	1	Salmon eggs	E
Penticton, B.C.	Mar. 1960	1	0	Salted Holland herring	E
Ketchikan, Alaska	Aug. 1960	2	2	Salmon egg "cheese"	E

Total cases 25; total deaths 18; case fatality rate 72 per cent.

Four type E outbreaks took place in southern British Columbia, at latitudes between 49° and 50°N. Of these, two occurred in coastal cities, at Nanaimo (Dolman and Kerr 1947) and Vancouver (Dolman *et al.* 1950); one at Natal, a rural community nearly 400 miles inland (Dolman 1953); and the other at Penticton, a city about 160 miles from the coast (Dolman 1961). The vehicles were home-canned salmon, home-pickled herring, home-pickled river trout, and imported salt herring.

The remaining 8 outbreaks, which occurred at latitudes ranging from 52° to 63°N., included 4 due to type E toxin and 1 to type B; in 3 others no bacteriological tests were made. Seven took place in coastal towns or settlements in northern British Columbia and southern Alaska, and the other on the Yukon River about 100 miles downstream from Whitehorse, Y.T. In each the vehicle was salmon eggs and the victims were Indians (Dolman *et al.* 1960, Williams 1960). Of the 18 persons affected, 13 died.

The high case fatality rate in this series of outbreaks — double the Japanese rate — is probably due partly to incomplete reporting of illness among Indians of the northern Pacific Coast, and partly to the semi-fluid, proteinaceous nature of fish eggs, which renders them a particularly suitable medium for toxin production. The morbidity rate for botulism in these areas is also considerably higher than in northern Japan, for their total population does not exceed 100,000 (less than one-fortieth that of Hokkaido). This heavy regional incidence can be attributed to the two chief factors cited earlier. The techniques used by the Indians in preparing salmon eggs for human consumption, details of which have been recorded elsewhere (Dolman *et al.* 1955, 1960), are potentially very botulogenic. Also, spores of toxigenic type E strains of *Cl. botulinum* are present in surprisingly large numbers on the ocean floor at various depths in certain localities along the British Columbia coast.

Such spores may survive for many months in samples of sea mud, collected in sterile vials and kept at around 5°C. For example, one specimen collected at Bute Inlet (50°30′ to 51°N.) early in July 1955 from a depth of 658 metres yielded a type E strain in pure culture when examined over 20 months later. Two others were negative. Near the end of 1959, 2 bottom samples taken about 6 months previously from the same inlet at 650 and 350 metres yielded type E strains, and 1 from 470 metres a type A strain. Botulism has not been reported among the few inhabitants of the vicinity of Bute Inlet, but fish-borne outbreaks have occurred about 125 miles to the south, at Nanaimo and Vancouver, B.C., and also some 175 miles north of the inlet, at Bella Bella, B.C. (Table 2, Fig. 2).

Nine bottom samples collected in shallower waters near Prince Rupert, B.C. during October and December 1959 from a coastal stretch between 53°20′ and 54°N. yielded 5 strains of *Cl. botulinum* type E. Three positive samples were collected at depths of 4, 22, and 24 metres, respectively; one came from 6 inches below the surface of the Oona River tide flat; and one from the bottom of the Kumealon River (depth about 1 foot) near the limit of tidal influence. In this general vicinity, at least two botulism outbreaks due to salmon eggs are known to have occurred, one involving 3 type E fatalities in 1957, and the other a single type B fatality in 1958 (Dolman *et al.* 1960).

Botulinus spores ingested by fish are liable to remain part of their intestinal flora. In fact, the prototype strains of *Cl. botulinum* type E were isolated in 1934-35 from the intestines of sturgeon in the Soviet Ukraine (Gunnison *et al.* 1936), where type A and B strains had been demonstrated earlier in similar fish (Dolman and Chang 1953). Subsequently, type E cultures were obtained from the intestinal contents of one out of 176 fish caught in northern France (Prévot and Huet, 1951); of 10 out of 12 dead fish floating in Hachiro Lagoon, Northern Honshu (Saito and Fujisawa 1955); of an unspecified number caught in Lake Abashiri, Hokkaido (Nakamura *et al.* 1956); and of a salmon caught in the Strait of Georgia, near Vancouver, B.C. (Dolman 1957b). Such intestinal spores represent

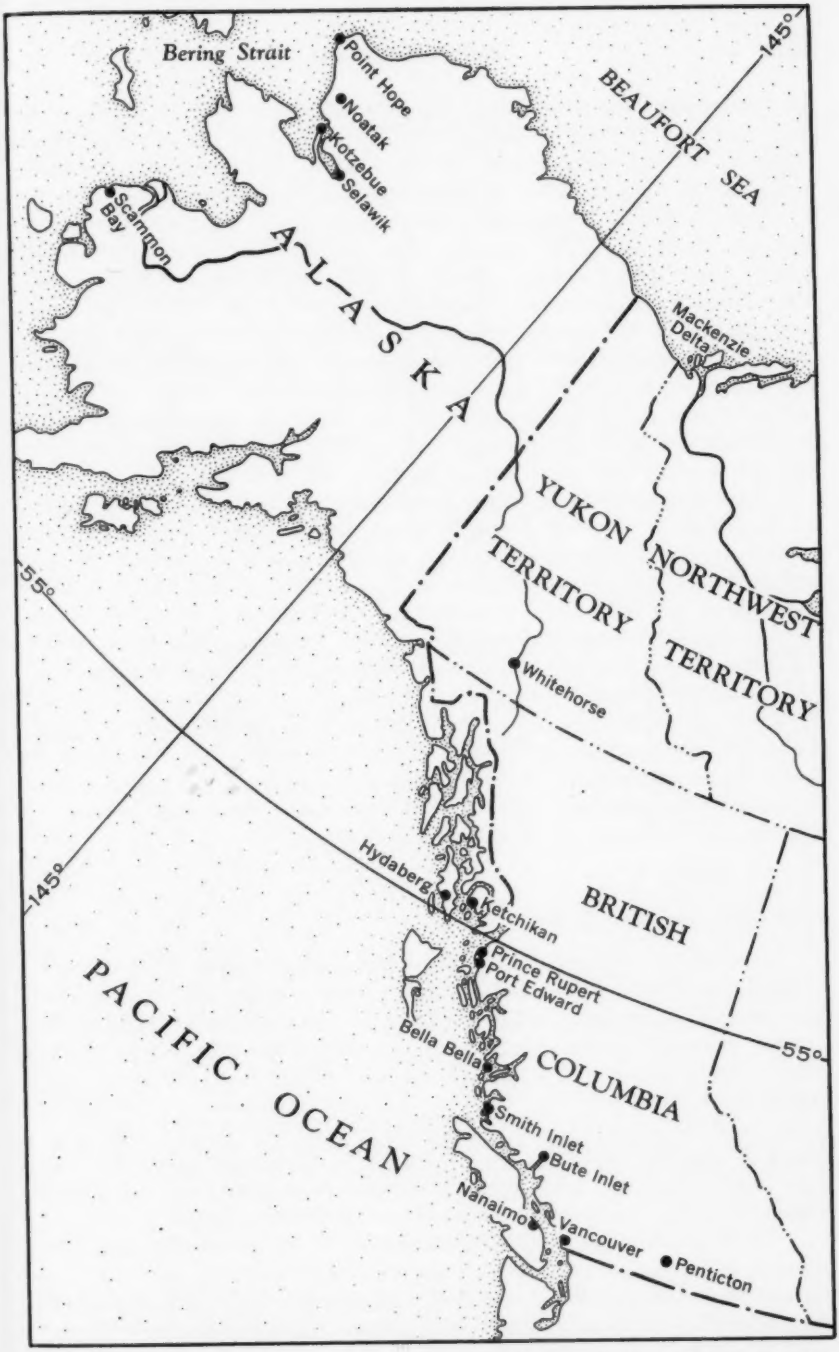


Fig. 2. Sites of botulism occurrences due to uncooked products of fish and marine mammals (and of *Cl. botulinum* isolations from sea bottom samples) in British Columbia, Alaska, and the Yukon.

an "endogenous" source of contamination when the fish are gutted or the eggs removed. If these procedures are carried out by persons with hands, utensils, or clothing polluted by fish faeces, the risks of introducing toxigenic spores into edible products are of course increased.

Alternatively, "exogenous" pollution of fish products may occur through direct or indirect contact with soil. Since Meyer and Dubovsky (1922) made their extensive survey of soil samples from various parts of the United States for types A and B botulinus spores, the telluric origin and widespread but erratic distribution of these spores has been generally accepted. Dolman (1957b) postulated that type E spore dissemination in some off-shore waters and submarine deposits may persist through proliferation of the organisms in the sea mud; but that such foci actually originate in the alluvial soil and terraqueous deposits of the adjacent shore, where in certain areas type E spores probably outnumber those of other types.

Northern Japan is one such area. Saito and Fujisawa (1956) isolated 18 type E strains from 146 samples of soil or mud taken from 35 locations in or near the Hachiro Lagoon. Nine of these isolates came from 26 specimens of lake bottom mud. Nakamura *et al.* (1956) isolated 6 type E strains from about 2000 specimens of mud from the shore of Lake Abashiri; and also 2 strains from 50 specimens of sand from the coast facing the Sea of Okhotsk. No cultures of other known botulinus types were identified.

Although there has been no opportunity to verify the possibility that type E spores predominate in the soil of those coastal areas of British Columbia and southeastern Alaska where fish-borne botulism seems to be endemic, it is noteworthy that *Cl. botulinum* type E was first isolated from soil during the investigation of a fatal outbreak of fish-borne botulism at Nanaimo, B.C., in 1945 (Dolman and Kerr 1947).

Outbreaks among Eskimos

Botulogenic conditions also prevail among the Eskimos of northwestern Alaska, the Northwest Territories, and Labrador, whose well-known liking for raw and parboiled fat and flesh of marine mammals has led to 13 authenticated outbreaks between July 1945 and July 1960 affecting 44 persons, with 23 deaths, i.e. a case fatality-rate of 52.3 per cent. (Table 3). In 5 instances, the foodstuff involved was "muktuk", or flippers of beluga (white whale, *Delphinapterus leucas*) preserved in seal oil; "utjak" (rotting seal flippers) was implicated on 3 occasions, and dried seal meat twice; seal liver, and fluke of the grey whale, *Eschrichtius glaucus*, were each responsible once.

The first 3 and the latest 2 outbreaks were not bacteriologically investigated. In 2 other recent episodes, the only specimens available for examination were a piece of human liver and stomach washings, respectively, which gave no significant results. Of 6 samples of implicated food remnants sent to the laboratory, 5 yielded type E strains of *Cl. botulinum* and the other a type A strain.

Table 3. Botulism outbreaks from consumption of marine mammals by Eskimos in Alaska, Northwest Territories and Labrador.

Place of occurrence	*Date of occurrence*	*Cases*	*Deaths*	*Foodstuff implicated*	*Type involved*
Markham Bay, N.W.T.	July 1945	8	7	Seal meat	?
Kotzebue, Alaska	July 1947	3	2	Beluga flippers	?
Noatak, Alaska	Aug. 1948	2	1	Beluga flippers	?
Point Hope, Alaska	Aug. 1950	5	0	Beluga flippers	E
Selawik, Alaska	July 1952	1	1	Beluga flippers	E
Kotzebue, Alaska	Aug. 1956	2	1	Beluga flippers	E
Ungadlek, Labrador	Dec. 1956	8	6	Seal flippers	E
Scammon Bay, Alaska	Oct. 1959	7	1	Grey whale fluke	E
Hopedale, Labrador	May 1960	4	2	Seal flippers	?
Hopedale, Labrador	June 1960	1	1	Seal liver	A
Nr. Hopedale, Labrador	June 1960	1	1	Dried seal meat	?
Nr. Hopedale, Labrador	July 1960	1	0	Dried seal meat	?
Nain, Labrador	July 1960	1	0	Seal flippers	?

Total cases 44; total deaths 23; case fatality rate 52.3 per cent.

Fig. 3. Sites of botulism outbreaks in Northwest Territories and Labrador. The salmon responsible for the first known type E outbreak was probably caught and smoked at Cartwright. *Cl. botulinum* type E was isolated from a sea bottom sample dredged at 350–400 m. depth from Agluitsok Bay, Greenland.

Markham Bay, N.W.T. Early in July 1945 7 Eskimos died after eating raw or parboiled seal meat in a camp numbering 23 men, women, and children, at Markham Bay, N.W.T. (roughly 63°30′N. 71°W., Fig. 3). Three adults, including the head man, and 5 children aged 7 to 15 years, were

affected by a syndrome which was unmistakably botulinic. An 8-year-old boy was the only survivor. Most of the victims lived in one tent and had eaten nothing but seal meat, sliced from a carcass kept unskinned on the ground inside the tent (Dolman 1953).

In the Canadian Eastern Arctic several seal carcasses are piled sometimes on the shore for 2 to 3 days before being skinned and eviscerated by their owners, when the offal is thrown to the dogs. In other Eskimo camps, the carcasses are kept together in the head man's tent for distribution later. Thus there are many opportunities for endogenous (intestinal) or exogenous (telluric) contamination of a seal carcass; and since no attempt is made to keep it frozen, a few days of mild weather might suffice to ensure production of lethal amounts of toxin in some parts of the meat.

Point Hope, Kotzebue, and Scammon Bay, Alaska. During the past 10 or 12 years several outbreaks of botulism have affected Eskimos inhabiting the coastal strip of northwestern Alaska between latitudes 62° and 68°N. (Fig. 2). The vehicle has generally been "muktuk", an Eskimo delicacy prepared by cutting the skin and underlying blubber of beluga flippers into chunks or strips that are dried on a rack for a period of 1 to 10 days. The pieces are then cured in a barrel of seal oil for at least 4 to 6 weeks, and sometimes for several months, in the comparative warmth of the hut (Rabeau 1960).

In 1947 and 1948, some deaths from botulism supposedly occurred at Point Hope, situated on the Arctic Ocean at approximately 68°N. 167°W., but as no details are available these outbreaks have not been included in Table 3. Late in August 1950 in the same locality, 5 members of a family of Eskimos aged 18 to 62 years developed mild botulism, from which they all recovered, after eating "muktuk" (Meyer and Eddie 1951). A sample of flipper was found to contain about 4 mouse minimal lethal doses (MLD) of type E toxin per gram, but the causal microorganism was not isolated (Meyer 1950). From a decomposed remnant sent to the author a few months later, a strain of *Cl. botulinum* type E (Fig. 1) was isolated that produced about 1000 mouse MLD per ml. in laboratory media (Dolman 1953; Dolman and Chang 1953).

During the period 1947-56 four outbreaks of botulism, all due to "muktuk", occurred at or near Kotzebue (67°N. 162°30′W.). The 8 affected Eskimos, of whom 5 died, were treated at the Alaska Native Hospital, Kotzebue. As Rabeau (1959) has reported these episodes, only their salient features will be outlined here. In July 1947 a 55-year-old man, his son aged 25, and his daughter-in-law aged 22 were admitted to hospital with severe symptoms of botulism, having eaten "muktuk" 16 hours before. The older man died about 50 hours and the young woman about 55 hours after the meal. The son eventually recovered, but was convalescent for 5 months. No food samples could be examined.

In August 1948 a 58-year-old resident of Noatak (67°30′N. 163°W) ate 3 pieces of "muktuk". His 16-year-old son ate a single piece. Twelve

hours later they developed symptoms of botulism, and after another 7 hours were admitted to hospital, where the man's condition grew worse despite administration of type A and B antitoxin. He died about 54 hours later. The boy recovered sufficiently to be discharged in 2 weeks. Again no samples were available for laboratory tests.

In July 1952 a 63-year-old male reached hospital with typical advanced botulism from a fishing camp near Selawik (60°30′N. 160°W.). Some 16 hours before the onset of illness he had eaten "muktuk". He died about 70 hours after consuming the suspected food, from a remnant of which a type E strain of *Cl. botulinum* was isolated.

In August 1956 a Kotzebue woman, aged 46, and her 8-year-old daughter were admitted to hospital with symptoms of botulism, which began 16 to 18 hours after eating "muktuk". The mother died suddenly 8 days later, and the daughter eventually recovered from a serious attack. Her 10-year-old brother, who also ate some of the food, had only gastric disturbances. From a small sample of the implicated "muktuk", Meyer and Eddie (1956) isolated a strain of *Cl. botulinum* type E (Dolman 1957a).

A fourth outbreak of type E botulism occurred at Scammon Bay (62°N. 166°W.), in October 1959. A boating party found the decomposed carcass of a grey whale, which had obviously been dead for some time. Many of the villagers did not heed warnings and ate portions of the flesh, feeding some to the dogs, without ill effects to man or beast. The fluke is prized for food, and next day 8 men ate various amounts of it uncooked. Within 24 hours 7 of them developed typical botulinic symptoms. Three were moderately ill, 4 severely, and one of the latter died on the third day. At the Regional Public Health Laboratory, Anchorage, unindentified toxin was demonstrated in extracts and cultures prepared from portions of the fluke (Pauls 1960).

Three samples from different parts of the fluke were forwarded to the author, along with some seal oil, the remains of a smoked salmon, and a sample of blood serum taken from the fatal case at autopsy. One of the fluke samples was non-toxic, another was slightly toxic, and the third contained between 200 and 600 mouse MLD of type E toxin per gram. From the last specimen a culture of *Cl. botulinum* type E was isolated, whose *in vitro* toxigenic capacity was 1000 to 3000 mouse MLD per ml. The salmon and the seal oil were atoxic, but the former yielded a type E strain whose toxigenic capacity was similar to that of the whale strain. The dead man's serum contained 3 mouse MLD per ml. of type E toxin.

The salmon and seal oil had been suspected at first as possible vehicles, but later it was learned that 2 of the victims had not eaten the fish dipped in the oil, whereas all had eaten whale meat. The salmon and the fluke were never in contact with each other, nor had they been cached in the same spot; but there were many opportunities for both to have been exposed to exogenous contamination by any botulinus spores present in the marine silt of the area. This particular salmon was not decomposed, but in preparing "tipmuk" — a common type of food cache in this region — salmon are heaped

into tightly enclosed pits lined with willow leaves and allowed to putrefy for at least one month. Then the material is used for both human and canine consumption (Philip 1960). Obviously "tipmuk" should be reckoned another potentially botulogenic Eskimo food.

A previous example of dual type E isolations during investigation of a single outbreak of botulism is afforded by the 1957 fatalities at Prince Rupert, B.C. Strains of similar characteristics were isolated from the implicated salmon eggs and from the stomach contents of one victim, but spores of an apparently distinct strain were present in a non-toxic sample of eulachon (Chinook = candlefish) oil found on the premises where the fish eggs had been prepared and eaten (Dolman 1960).

Nain and Hopedale, Labrador. In December 1956 an outbreak of botulism occurred among a hunting party of Eskimos at the sealing station of Ungadlek, some 35 miles east of Nain (roughly 56°30′N. 61°30′W.). At a noon meal 6 men and 2 girls, aged 6 and 8 years, ate some "utjak" that had been stored in an unclean metal cask for 10 days at a temperature range of 20° to 40°C. Within 24 hours the younger girl and 4 men had died of typical acute botulism. Another man died on the third day. The older girl and one man had vomited soon after the meal and recovered in hospital. A similar tragedy had occurred in this area in 1954, at which time the natives were warned of the dangers of eating rotten seal meat (Brocklehurst 1957).

"Utjak", a favourite dish among Eskimos in the Eastern Arctic, is traditionally prepared by placing seal flippers, complete with fur, in a wooden cask, which is left, covered with a lid, behind the stove for several days. In this instance an unwashed gasolene drum was used in which sealskins had been stored the year before. One of the remaining flippers, heavily coated with rancid seal oil, was forwarded deep-frozen to the author. The flesh contained 600-1000 mouse MLD per gram, and a strain of *Cl. botulinum* type E, capable of producing toxin of 1000-3000 mouse MLD per ml., was readily isolated from it (Dolman 1957a).

In May 1960 a similar outbreak occurred at Hopedale (approximately 55°30′N. 60°30′W.). Four Eskimo women ate rotting seal flipper that had been kept near a stove for some 10 days in a metal container. After about 24 hours 2 women, aged 49 and 18, developed abdominal cramps, vomiting, and diarrhoea, followed by epigastric pain, visual disturbances, and dysphagia. Both died in respiratory failure, the older woman within 48 hours of the meal, and the other a few hours later. Two other women, found to be suffering from gastrointestinal and visual disturbances, and dysphagia, were brought to hospital by helicopter, where type E antitoxin was administered intramuscularly. Both made a good recovery. No food samples were available for laboratory examination. A piece of liver, taken at autopsy, was forwarded deep-frozen to the author. A saline extract of this material contained no detectable botulinus toxin, and *Cl. botulinum* could not be isolated from it.

Three weeks later, in June 1960, another fatality occurred at Hopedale.

A woman, aged 35, was the sole consumer of some raw seal liver taken from a carcass that had lain in a warm porch-way for 3 days. Within 12 hours of the meal, she developed vomiting, diplopia, dry mouth, and dyspnoea. She died shortly before a physician arrived. A remnant of the implicated seal liver and the patient's stomach washings were relayed in dry ice to the author. Both specimens were atoxic, but the liver yielded a type A strain of *Cl. botulinum*, which produced roughly 100,000 mouse MLD per ml. of culture medium.

In the same vicinity, 12 days later, a 59-year-old Eskimo male fell ill after eating dried seal meat. He died shortly after arrival in Hopedale. A sample of stomach washings was atoxic and proved bacteriologically negative. Within a few days dried seal meat caused another severe case at Hopedale. Type E antitoxin was administered after typical symptoms had been present for 24 hours, and the patient made an uneventful recovery. Finally, early in July 1960, a male recovered from botulism at Nain, the vehicle being seal flippers (Paddon 1960). In none of these last two instances were specimens available for laboratory examination.

The outbreaks cited do not represent all occurrences of botulism among Labrador Eskimos. In the past decade or so, according to Paddon (1960), persistence in eating "utjak", particularly among the older generation, has caused "a good many deaths". There are no recorded instances of botulism affecting the white man in the Arctic; but it may be recalled that the first known type E outbreak at Cooperstown, N.Y. in 1932 was due to Labrador salmon, probably caught and prepared near Cartwright. The fish had been smoked and coated with wax before being shipped and was not subsequently cooked.

European occurrences

Very few type E outbreaks and isolations have been reported from Europe. Apart from a few exceptional foci, spores of this type must be comparatively rare in the soil and adjacent seas of the continent.

Russia. After Kushnir's isolation of the prototype E strains from sturgeon caught in the Sea of Azov (Dolman and Chang 1953), only one account of a proven type E episode can be traced in the Russian literature. In 1938 at Leningrad (60°N. 30°E.) a man died after eating smoked herring, from remnants of which a type E culture was isolated (Zavadovskaya 1940). Earlier, Kurochkin and Emelyanchik (1937) had described 3 outbreaks of botulism in 1934 and 1935 on the northwest shores of the Caspian Sea, several hundred miles east of the Sea of Azov. In each instance the vehicle was salted uncooked meat and blubber from seals *(Phoca sibirica)*, which the local inhabitants occasionally eat. The first outbreak at Astrakhan (roughly 46°30′N. 48°E.) affected 3 persons, of whom 2 died. In the earlier of 2 outbreaks at Guryev (47°N. 52°E.), which together caused 5 deaths, extracts of incriminated seal meat contained toxin unneutralized by type A and B

antitoxin. The meat yielded a culture of *Cl. botulinum* whose reported characteristics warrant its retrospective identification as a type E strain.

The latest review of botulism in the Soviet Union (Matveyev and Gannushkin 1958) states that type E spores (as well as type A, B and C) have been found in the soil of the USSR, but gives no localities. There is no reference to botulism as a problem of the Far North.

France. Prévot *et al.* (1951, 1952 a, b) reported 3 fish-borne botulism episodes in different parts of France, which they considered probably due to type E toxin, although proof was wanting. There were no clues to the sources of contamination. Since marine species were involved, spores could have been ingested by the fish in the Bay of Biscay, the English Channel, or wherever they were feeding before being caught. Alternatively, as the outbreaks were all inland, terrestrial pollution might have occurred anywhere between the coast and the places cited, which lie within a comparatively large area of France from around 43° to 50°N. The isolation by Prévot and Huet (1951) of a type E strain from the intestinal contents of a freshwater perch *(Perca fluviatilis)* taken from a pond south of Paris, suggests that spores of local telluric origin might be the source of trouble in some parts of the country. In a second survey Prévot and Brygoo (1953) isolated type A strains from the intestines of 3 out of 133 fish caught in the same area.

Denmark. In October 1951 an outbreak of botulism occurred at Frederiksberg, Denmark, due to uncooked vinegared herring, which yielded a type E culture. Six persons were severely affected, but none died. Subsequently, the presence of type E spores was demonstrated in 12 out of 15 sea mud specimens collected at depths of 3 to 6 metres from the fish market canal and other parts of Copenhagen harbour (Pedersen 1955).

Among 10 outbreaks of botulism recorded in Denmark over the period 1901-58, there have been 3 others in which the vehicle was uncooked fish. Whereas in the Frederiksberg episode every victim recovered, in these earlier instances all 9 affected persons died. Salted mackerel was implicated in one outbreak, and salted herring in the two others. The types of *Cl. botulinum* involved were not identified (Jensen and Hahnemann 1959).

The Baltic and North Sea. Focal concentrations of type E spores may exist elsewhere around the shores of the Baltic Sea. For example, at Westchester County, N.Y., in 1934 typical botulism developed in 3 adults, one of whom died, after eating canned sprats ("Kielersprotten") imported from Kiel, Germany (Hazen 1937). The toxigenic organism isolated from them was shown later to be a type E strain (Hazen 1938).

Type A spores are also apparently present in this vicinity. Wasmuth (1948) has recorded 30 cases of botulism in the 3-year period 1945-8, affecting inhabitants of Kiel and the surrounding areas of Schleswig, the usual vehicle being vinegared herring. In a few instances type A toxin or organisms could be demonstrated in the implicated fish, or in stomach contents.

By contrast, the North and Norwegian seas seem relatively free of botulinus spores. There is no record of such spores being identified in sea bottom or shore samples from these regions, perhaps because there have been few systematic attempts. An opportunity arose 2 or 3 years ago to examine in this laboratory samples of sea mud collected a few months earlier, at depths ranging from 140 to 400 metres, from subarctic and arctic fishing grounds in the Norwegian Sea. None of the 19 specimens yielded toxic cultures.

In the British Isles botulism due to locally caught fish is unknown. Two type A cases reported from England (Mackay-Scollay 1958) were due to fish caught and pickled in Mauritius 4 weeks before. In Norway, where much salted fish is consumed, out of a total of 10 occurrences to date only 2 inland episodes, each involving single individuals, have been fish-borne. The vehicle was "rakefisk", a Scandinavian dish in which trout *(Salmo trutta),* freshly caught in mountain lakes, are layered with salt under pressure in a wooden tub and stored in a cool place. Seven of these outbreaks (including the fish-borne ones) were due to type B toxin (Skulberg 1958, 1960). The only plausible example of botulism traceable to North Sea fish is the recent type E case at Penticton, B.C.; but even here it is possible that the keg of salted Holland herring became contaminated in British Columbia, either during storage or while its contents were being prepared for consumption (Dolman 1961).

Discussion

This report poses two main problems. The first, mainly theoretical, relates to the peculiar geographic distribution of type E spores. The second is concerned with the practical steps necessary to avert dangers resulting from germination of botulinus spores in foodstuffs prepared from fish and marine mammals such as are consumed by the Eskimos and other natives of the Far North.

Cl. botulinum type E, unlike types A to D, is not known to have been isolated in the southern hemisphere. Indeed, the epidemiological evidence to date indicates that type E spores occur in significant numbers only at latitudes higher than 40°N.; and further, that their heaviest disseminations are in northern Japan, and in scattered foci along the northwest Pacific Coast, and the subarctic and arctic perimeter of North America. These restricted localizations provoke certain questions. What factors make the northern hemisphere, and particularly lands bordering the northern Pacific Ocean, especially liable to type E botulism? Why do not similar outbreaks occur, for instance, in Lapland or northern Siberia? And why are type E strains predominantly involved in botulism due to foodstuffs of marine origin? Partial answers to some of these questions have been offered previously, based on the supposition that type E spores, although telluric in origin, have a special affinity for the ocean floor, and for terraqueous deposits of the littoral in colder areas, where they may intermittently

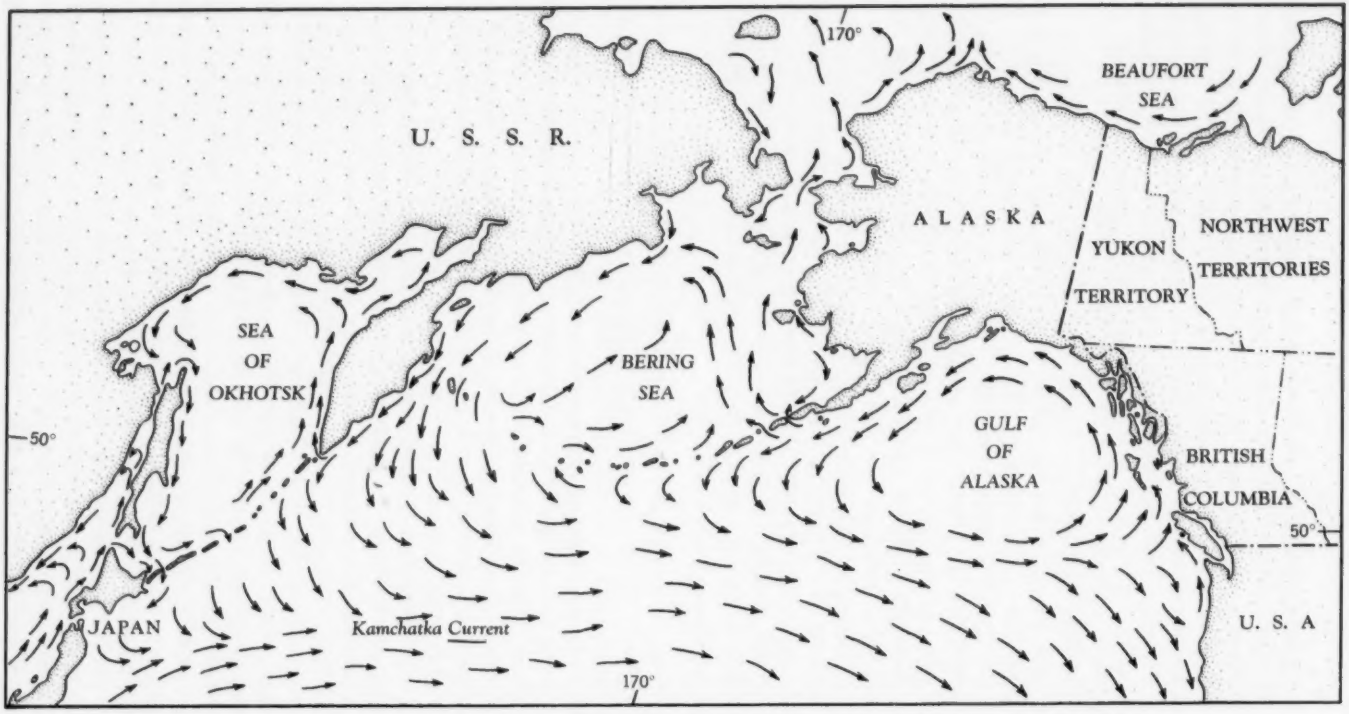


Fig. 4. North Pacific Ocean and contiguous seas, showing main currents in relation to continental land masses.

germinate and proliferate (Dolman 1957b). This hypothesis, with some embellishment, still seems valid.

Ten years ago it was first noted (Dolman *et al.* 1950) that type E toxin can be produced at a temperature of 6°C. Ohye and Scott (1957) showed further that type E strains grow and produce toxin over a temperature range 5° to 10°C. lower than do type A and B strains. These observations help to explain the tendency for type E botulism to preponderate in colder climates, and also to refute the claim of Abs (1959) that optimum temperatures for the growth of *Cl. botulinum* are probably not attainable in arctic latitudes. It is perhaps unnecessary to add that Abs errs in asserting that "botulism has not yet been demonstrated in the Arctic".

The predilection of type E botulism for the northern hemisphere is no doubt due to various factors, ranging from the direction and velocity of ocean currents, and prevailing water and air temperatures, to the ecology of the causal microorganism and the dietetic customs of the inhabitants. Their interrelationships are too complex and uncertain for discussion now, but certain points seem relevant. The northern hemisphere comprises most of the world's land mass, and a correspondingly small proportion of ocean waters in which terrestrial spores can be dispersed. At higher latitudes, the ratio of land mass to water volume increases, especially in the Pacific area. Between the parallels 45° and 50°N. the widely separated coastlines of eastern Asia and western North America are linked by the well-marked Kamchatka Current, flowing eastward. Farther north, the great expanse of the Pacific Ocean narrows and is divided into the Sea of Okhotsk, the Bering Sea, and the Gulf of Alaska, all bordered by mountainous territory; and the uni-directional current traversing the main ocean merges with, or gives rise to, 3 separate regional currents circulating counter-clockwise within these lesser seas (Fig. 4). Finally, at the Bering Strait, where the continents almost touch, a north-flowing current skirts the coast of western Alaska.

Ohye and Scott (1957) deduced from the relatively low temperature range of type E strains that their natural habitat is marine rather than terrestrial. In that event, they should differ — but do not — from type A and B strains in ability to survive in sea water, and in sodium chloride tolerance (see below). Nearly 40 years ago Meyer and Dubovsky (1922a) suggested type A botulinus spores had an affinity for the primordial soil of certain California mountain ranges. A comparable postulate for type E spores, combined with the above geographic and oceanographic considerations, helps to explain their presence in the sea mud, silt, or sand of areas where the incidence of type E botulism is high. Thus, the waters and terraqueous deposits surrounding the rugged island of Hokkaido, or encroaching upon the rainy, mountainous coastline of British Columbia and Alaska, are bound to reflect to an unusual degree the bacteriological flora of the nearby land. Germination and multiplication in marine and littoral foci where micro-environmental conditions are propitious could then account for the findings of Saito and Fujisawa (1956) and of Nakamura *et al.*

(1956) that the concentration of type E spores in lagoon bottom mud and coastal sand may be much higher than in neighbouring soil. Spores can also be transported far and wide by tides and currents, or by fish and marine mammals which ingest and in due course excrete them, perhaps in substantially increased numbers. Thus, three mechanisms — the erosion of mountain slopes, the infiltration of sea water lapping the shore, and the migratory habits of fish and marine mammals — may convey spores to coastal areas at various distances from their origins, the final distribution patterns being determined largely by the course of rivers and streams, and by the flow of ocean currents and tides.

The foregoing hypotheses seem compatible with the known distribution of type E botulism in the northern Pacific and contiguous subarctic and arctic regions (see Figs. 4 and 5). They also permit some deductions about the likelihood of the disease occurring among other northern natives. For instance, the disseminations of type E spores in the littoral of Hokkaido and in adjoining parts of northern Honshu, may derive not only from inland mountains, but also from ranges on the Kamchatka Peninsula and adjacent areas of eastern Siberia bordering the Sea of Okhotsk; for the currents hereabouts are such as to encourage the scourings of this sea to be deposited on or near the coasts of northern Japan. Hence, type E botulism might well occur among the Kamchadals and any other native peoples of eastern Siberia who eat raw fish or marine mammals, though the disease could be as unrecognized there as it was in Japan until less than 10 years ago.

The concentration of spores in the vicinity of Prince Rupert, B.C., could be due to the northerly arm of the bifurcating Kamchatka Current intermingling here with the outflow of the Skeena River and the lesser tidal streams that drain the slopes of the Coast Mountains. The ultimate source of these spores therefore may have been thousands of miles away in Kamchatka, or perhaps only a few miles inland. Again, a current sweeping slowly northwards along the west coast of Alaska would tend to deposit spores in heaviest concentration near the Bering Strait bottleneck, i.e. along that very stretch of shoreline from Scammon Bay to Point Hope where all known outbreaks among Alaskan Eskimos have occurred. Since the opposite coast lies in the path of a contrary current flowing southward from the East Siberian Sea, it could escape being seeded with type E spores, so that botulism might be unknown among the Eskimos of the Chukotski Peninsula, despite dietetic customs similar to those prevailing across the Strait.

The liability of Labrador Eskimos to type E botulism probably derives from a similar complex of geographic, oceanographic, ecologic, and dietetic factors. The outbreaks in the Nain and Hopedale regions should be considered in relation to the isolation by Pedersen (1955) of a toxigenic type E culture from a sample of sea mud trawled from the bottom of Agluitsok Bay (about 60°N. 45°W.) on the southwest tip of Greenland. The suggestion has been made previously (Dolman 1957b) that these facts may be linked by the well-defined northerly current that washes the west coast of Greenland and

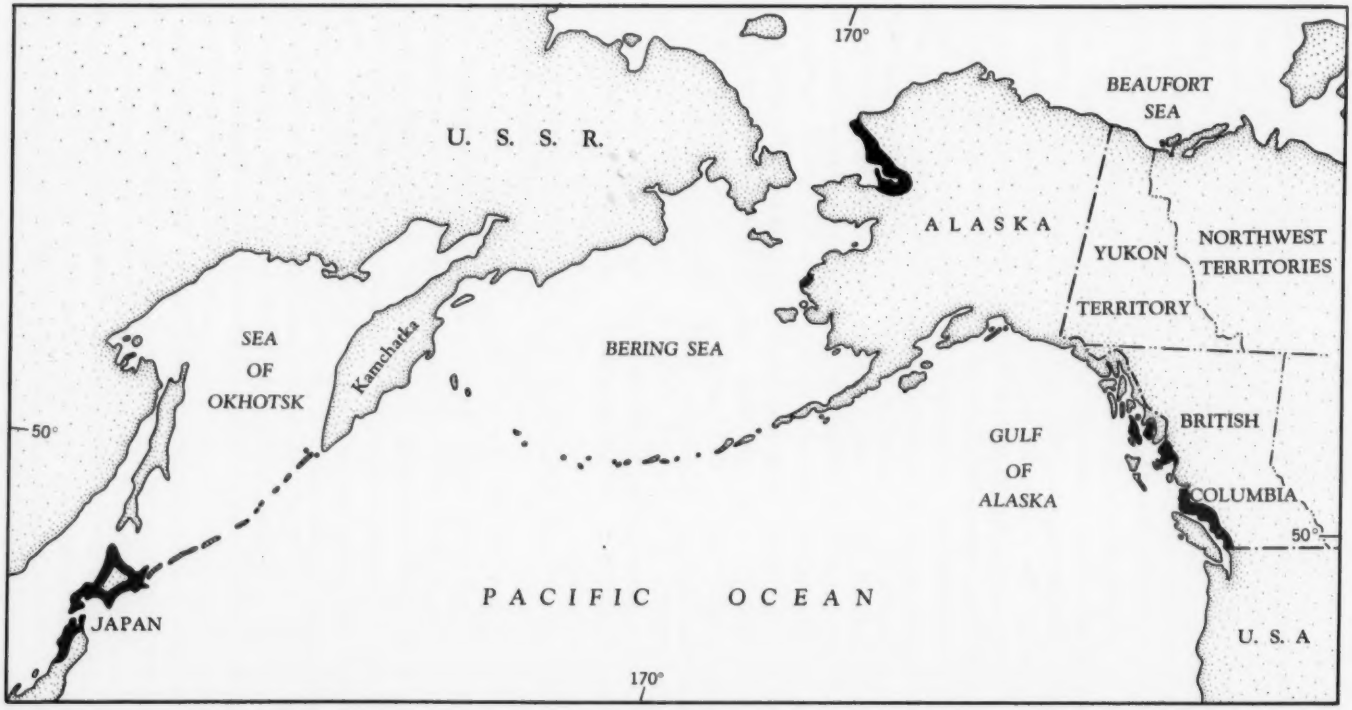


Fig. 5. Foci of endemic type E botulism due to consumption of raw marine foodstuffs, involving coastal fringes of northern Japan, British Columbia, and Alaska. Compare with Fig. 4.

turns southward in Davis Strait to become the Labrador Current. Thereby type E spores from the mountains and fiords of southwest Greenland and of northeast Labrador could be picked up and deposited along the littoral a few hundred miles farther south. In other words, unless the western Greenland Eskimos have distinctive dietetic habits they may be exposed to the risk of type E botulism.

The absence of recorded botulism in northern Europe and Asia invites comment. Although the misadventures of distant native peoples do not always come to the attention of the central governments concerned, it seems improbable that the authorities in, e.g., Norway, Sweden, and Finland, would be unaware of the public health hazards faced by the Lapps. Nor is it likely that botulism endemic to the Siberian Arctic would pass unrecognized. "Fish poisoning" has been prevalent around the Caspian Sea, and its symptomatology discussed frequently in the Russian medical literature for over 100 years, and the botulinic nature of the disease has been known to Russian bacteriologists for half a century (Dolman and Chang 1953). Yet the diet of the inhabitants of the remote northern fringes of the USSR (such as the Skolts of Russian Lapland, the Chukchi of the northeastern Siberian Arctic, and the Kamchadals) does not lack botulogenic components. In a review of dietary habits in Finnish Lapland Latsky (1955) states that reindeer meat may be eaten uncooked in dried, smoked, or slightly salted form; and reindeer stomachs, filled with blood or milk, are buried in the snow or slowly dehydrated over a fire for several weeks or months before consumption of their contents. Raw fish is also eaten dried or smoked, or slightly salted and soured. On such a diet, if spores were as numerous in these parts of the world as they apparently are in the other areas cited, outbreaks of botulism would seem inescapable. As things are, it is necessary to postulate a paucity of all types of botulinus spores in the far northern littoral of Europe and Asia.

This postulate is consistent with the irregular distribution of type A and B spores, recognized since the soil surveys of Meyer and Dubovsky (1922 a, b, c), and also with the evidence collected here pointing to variations in the incidence of type E spores. At present, regional telluric dearth or abundance of botulinus spores cannot be explained. However, it seems plausible to invoke geographic and oceanographic considerations again to account for the presumed failure of water-borne type E spores to reach the arctic shores of these continents. Whereas northern Japan, western Alaska, and central Labrador are impinged upon by cold ocean currents, which have lapped the littoral of regions where the ratios of land mass to water volume are high, the reverse holds for the regions in question. The North Atlantic Drift Current, which passes tangentially up the Norwegian coast and turns eastward to skirt the Kola Peninsula, is relatively warm, mainly owing to its Gulf Stream component. Moreover, in its long northeasterly passage across the Atlantic and on through the Norwegian and Barents seas to the Arctic Ocean, this current is unimpeded by funnel-like convergences or massive interpositions of land, so that any spores carried

by it would be subject to an extremely high dilution factor, as well as to comparatively scant opportunities for terrestrial settlement.

If a high incidence of type E spores in the terraqueous deposits of certain parts of the Northern Hemisphere is accepted as a plausible explanation for the close association between type E botulism and marine products, the question naturally arises whether their preponderance over type A and B spores in such environments can be accounted for in terms of experimentally detectable differences in, e.g., ability to survive or to vegetate and proliferate in sea water. In a vain attempt to elucidate this possibility, several laboratory tests have been carried out, the details of which will be published elsewhere. In sum, the results showed no significant differences in the survival of heavy inocula of type A, B, and E spores in sterilized sea water kept at 3° to 5°C; no definite decline in numbers of viable spores after 80 days; and possibly some occasional proliferation (regardless of type) during this period. In another series of experiments, spores were able to vegetate and multiply at 30°C. in appropriate media containing up to 4 to 6 per cent NaCl, and under these conditions equal tolerance to sodium chloride was shown by the 3 types of spores.

A problem of prime importance remains for brief discussion, viz., the possible means of reducing or eliminating the hazard that endemic botulism presents to certain native peoples of the Far North, especially the Eskimos. In the 12 months preceding compilation of this report, of no fewer than 9 outbreaks coming to the author's attention, 2 were among Indians in southeastern Alaska, and 6 affected Eskimos in Labrador and northwestern Alaska. There were 8 deaths among a total of 18 affected natives. This was apparently an exceptional year, but such figures probably reflect the actual incidence of the disease more nearly than do those previously reported. Theoretically, control measures (none of them easily applied) range from the overthrow or modification of long established dietary customs to the induction of specific immunity. Endemic type E botulism is most likely to occur in localities where type E spores abound and where the people prefer to eat their sea foods raw. Since the spores cannot be dispersed, protection is only possible through changes in food habits.

Type E spores and all types of botulinus toxins are destroyed by moderate heat. A foodstuff heated throughout to 80°C. for 30 minutes, or to 100°C. for 10 minutes, will contain few if any viable type E spores and little or no type A, B, and E toxin. Indeed, these toxins are so thermolabile (Prévot and Brygoo 1953) that intimate exposure of all parts of a butolinic food for only a few minutes to 60°C. should reduce the toxicity to insignificant levels. However, type A and B spores (especially the former) whose occasional involvement in botulism among Eskimos and Indians has been illustrated are usually very heat resistant. Hence, aside from inherent risks of recontamination with type E spores, a foodstuff such as "muktuk", heated to the above extent, but subsequently immersed in seal oil for several days or weeks, could not be reckoned safe. These foods can be made safe only by sufficient heating very shortly before their consumption. For the Eskimos, an added

advantage of this heat treatment would be protection against trichinosis.

The proposed violation of time-honoured recipes may be rejected by these natives because the desired flavour will be lost; it may be scorned in defiance of the white man's encroachments and paternalism; or ignored when fuel is scarce, time short, and hunger rampant. But since type E organisms are nonproteolytic, foods containing dangerous amounts of type E toxin may be unaltered in taste, odour, or appearance. Moreover, neither gustatory discrimination nor self-inflation guarantees longevity. In time, acculturation will change the picture, but meanwhile it should be made clear to those concerned that mortal dangers may lurk in some of their traditional foods. The responsibility for translating this advice into simple, forceful terms rests with public health and other responsible officials.

Refrigeration, whether natural or mechanical, must be ruled out as an alternative method of temperature control in this context. Natural refrigeration is unreliable and impracticable, even for Eskimos. In winter, seal carcasses are liable to be stored inside dwelling-places, "utjak" even being kept near a stove to mature. In summer or early autumn, when most of these botulism outbreaks occur, quite high outdoor temperatures may prevail along the Alaskan and Labrador coasts. Mechanical refrigerators, apart from being at present out of reach of the average Eskimo and Indian, would not guarantee protection, since type E toxin can be produced at a temperature as low as 6°C.

A useful degree of active immunization against type A, B, and E botulism could probably be accomplished by inoculating populations at risk with trivalent botulinus toxoid. However, this is impracticable, owing to the difficulties of administering multiple doses at suitably spaced intervals to scattered and often migratory groups of all ages. On the other hand, administration of botulinus antitoxin could be life-saving, provided the appropriate serum was given soon after the onset of symptoms. A small quantity of type E antitoxin, prepared by the Connaught Medical Research Laboratories, University of Toronto, in co-operation with the Defence Research Board of Canada, has been made available for clinical trial in suitable areas. In five cases treated with this antitoxic serum — two in northern Japan and three in Labrador — the results were very encouraging. Such a monovalent preparation can only be effective against an intoxication of homologous type. The form of botulism under review is generally, but not exclusively, due to type E toxin, and the need seems urgent for supplies of trivalent botulinus antitoxin to be manufactured and kept accessible in regional depots where the disease is endemic.

Detailed discussion of the specific and symptomatic treatment of botulism would not be appropriate in this paper. But a few final comments seem pertinent on what should be done when the disease strikes in e.g. an Eskimo settlement. Any case of suspected botulism should be regarded as an emergency, requiring prompt hospitalization with transportation of the affected persons by air, regardless of cost. Pending the arrival of plane or helicopter, equipped if possible with a mechanical respirator, the most

important first aid measure is to empty and thoroughly irrigate the stomach. In the absence of doctor or nurse, the nearest missionary, teacher, or policeman who knows how to pass a stomach tube should carry out this procedure, using an alkaline solution such as 2 to 5 per cent sodium bicarbonate in water. The 3-fold purpose is: to evacuate botulinic material not yet absorbed; to expose unabsorbed toxin to alkaline pH levels, at which all types of botulinus toxins become unstable; and to minimize the tryptic activation process, primarily affecting type E toxin, whereby in the presence of trypsin at a pH range of 5.5 to 6.5, the lethal potency of this toxin undergoes a manifold increase for mice and men (Dolman 1957b). This last-mentioned property of type E toxin no doubt contributes to the special element of unpredictability about the outcome when botulism attacks the inhabitants of northern Japan or the coastal Indians and Eskimos of North America.

Summary and Conclusion

Botulism due to consumption of uncooked products of fish and marine mammals occurs endemically in certain regions of the northern hemisphere. Type E strains of *Clostridium botulinum* are usually involved. Since this microorganism was identified 25 years ago, 50 outbreaks of type E botulism have been reported, affecting 242 persons, of whom 85 died — an overall case fatality rate of 35.1 per cent. About three-fifths of these outbreaks, involving roughly three-quarters of the total cases and deaths, have been recognized within the last decade in northern Japan, where fermented rice cakes containing raw fish ("izushi") have been almost exclusively implicated.

Four of the remaining proven type E outbreaks have affected coastal Indians of northern British Columbia and southeastern Alaska, the vehicle being raw salmon eggs prepared and stored insanitarily. In 5 episodes, Alaskan or Labrador Eskimos have been attacked, following consumption of beluga flippers ("muktuk"), whale fluke, or seal flippers ("utjak"). There are several additional reports of botulism among these North American native groups, based on clinical and epidemiological evidence but lacking bacteriological confirmation; and hearsay evidence indicates that many other cases have gone unreported. In the last 15 years traditional Eskimo foods prepared from marine mammals have proved botulogenic in 13 outbreaks, altogether involving 44 persons, aged 6 to 59 years, of whom 23 died (52.3 per cent). This form of botulism is a more hazardous disease than arctic trichinosis, with which it may have been confused at times, despite few resemblances. Since adequate heating of such foods shortly before consumption alone ensures their safety, control of the disease presents a major challenge in public health education, particularly among the Eskimos ("those who eat raw flesh").

Supplies of trivalent botulinus antitoxin of type A, B and E, should be made available in endemic areas for emergency use. Encouraging results

have been obtained in a few cases treated with type E antitoxin, but the monovalent product would be useless in the occasional type A or type B outbreak due to raw marine products, of which single instances are cited. Thorough stomach washing with sodium bicarbonate solution is suggested as an important first aid measure.

Oceanographic and other factors are discussed that seem to determine the peculiar distribution of type E spores in sea mud and other terraqueous deposits of the littoral in northern Japan and in arctic and subarctic regions of North America. Heavy disseminations of such spores in these areas, combined with very botulogenic dietary habits among the local natives, account for and are believed to justify the title of this review.

Acknowledgements

Besides those whose communications are referred to in the text, the following persons have co-operated in various ways. Dr. J. E. Josephson, Director of Laboratories, Department of Health, Newfoundland; Dr. R. N. Philip, Chief, Epidemiology Section, and Mr. F. P. Pauls, Bacteriologist, Arctic Health Research Center, Anchorage, Alaska; Dr. R. B. Williams, Director, Public Health Laboratories, Alaska Department of Health; and Dr. A. Roundhill, the International Grenfell Association, Labrador, provided data on outbreaks and forwarded specimens. Dr. G. L. Pickard, Director, Institute of Oceanography, University of British Columbia; Dr. J. M. Shewan, Director, Torry Research Station, Aberdeen; and Mr. M. R. Rondelet, Skeena Health Unit, Prince Rupert, B.C., procured sea bottom samples. Misses M. Tomsich, L. Murakami, and J. Colosimo, and Mr. C. C. R. Campbell, rendered valuable technical assistance; and Mrs. M. Irving prepared the maps. All this help is gratefully acknowledged.

References

Abs, O. 1959. Die Eskimoernährung und ihre gesundheitlichen Auswirkungen, Leipzig: G. Thieme, 107 pp. (Sammlung zwangloser Abhandlungen aus dem Gebiet der inneren Medizin. Heft 7. Herausgeber: Prof. Dr. G. Katsch).

Brandly, P. J., and R. Rausch. 1950. A preliminary note on trichinosis investigations in Alaska. Arctic 3:105-7.

Brocklehurst, J. C. 1957. Fatal outbreak of botulism among Labrador Eskimos. Brit. Med. J. 2:924.

Brown, M., B. Cronk, F. de Sinner, J. E. Green, J. E. Gibbons, and E. Kuitunen-Ekbaum. 1949. Trichinosis on Southampton Island, N.W.T. Canad. J. Pub. Health 40:508-13.

Connell, F. H. 1949. Trichinosis in the Arctic: a review. Arctic 2:98-107.

Dolman, C. E. 1953. Human botulism in Canada. Canad. Med. Ass. J. 68:538-43.

———1957a. Recent observations on type E botulism. Canad. J. Pub. Health 48:187-98.

———1957b. Type E (fish-borne) botulism: a review. Japan J. Med. Sci. and Biol. 10:383-95.

———1961. Further botulism episodes in Canada. Canad. Med. Ass. J. (In press).

Dolman, C. E., and H. Chang. 1953. The epidemiology and pathogenesis of type E fish-borne botulism. Canad. J. Pub. Health 44:231-44.

Dolman, C. E., H. Chang, D. E. Kerr, and A. R. Shearer. 1950. Fish-borne and type E botulism: two cases due to home-pickled herring. Canad. J. Pub. Health 41:215-29.

Dolman, C. E., G. E. Darby, and R. F. Lane. 1955. Type E botulism due to salmon eggs. Canad. J. Pub. Health 46:135-41.

Dolman, C. E., and D. E. Kerr. 1947. Botulism in Canada, with report of a type E outbreak at Nanaimo, B.C. Canad. J. Pub. Health 38:48-57.

Dolman, C. E., M. Tomsich, C. C. R. Campbell, and W. B. Laing. 1960. Fish eggs as a cause of human botulism. Two outbreaks in British Columbia due to types E and B botulinus toxins. J. Infect. Dis. 106:5-19.

Fay, F. H. 1960. Carnivorous walrus and some arctic zoonoses. Arctic 13:111-22.

Gunnison, J. B., J. R. Cummings, and K. F. Meyer. 1936. Clostridium botulinum type E. Proc. Soc. Exper. Biol. and Med. 35:278-80.

Hazen, E. L. 1937. A strain of B. botulinus not classified as type A, B or C. J. Infect. Dis. 60:260-4.

———————1938. Incitants of human botulism. Science 87:413-4.

Iida, H., Y. Nakamura, I. Nakagawa, and T. Karashimada. 1958. Additional type E botulism outbreaks in Hokkaido, Japan. Japan J. Med. Sci. and Biol. 11:215-22.

Iida, H. 1959-60. Personal communications.

Jensen, B. B., and F. Hahnemann. 1959. Botulism. Reports of two similar epidemics. Ugeskr. Laeger. 121:1363-8. (In Danish).

Kurochkin, B., and K. Emelyanchik. 1937. Seal meat as a source of botulism. Vopr. pitan. No. 1, 141-8. (In Russian).

Latsky, J. M. 1955. Dietary habits in Finnish Lapland. Some personal investigations. S. Afr. Med. J. 29:794-6.

Mackay-Scollay, E. M. 1958. Two cases of botulism. J. Path. and Bact. 75:482-5.

MacKenzie, G. M. 1934. Three cases of botulism treated with antitoxin. Clinical Miscellany, Mary Imogene Bassett Hospital, Cooperstown, N.Y. 1:53-63.

Matveyev, K., and M. Gannushkin. 1958. Botulism. Bol'shaya Medits. Entsiklop. 4:266-87. (English trans. from Office of Technical Services, U. S. Dept. of Commerce, Washington, D.C.).

Meyer, K. F. 1950. Personal communication.

Meyer, K. F., and B. J. Dubovsky. 1922a. The distribution of the spores of B. botulinus in California. 1922b. . . . in the United States. 1922c. . . . in Belgium, Denmark, England, the Netherlands and Switzerland. J. Infect. Dis. 31:41-55, 59-94, 100-109.

Meyer, K. F., and B. Eddie. 1951. Perspectives concerning botulism. Zeit. f. Hyg. 133:255-63.

———————1956. Personal communication.

Nakamura, Y., H. Iida, K. Saeki, K. Kanzawa, and T. Karashimada. 1956. Type E botulism in Hokkaido, Japan. Japan J. Med. Sci. and Biol. 9:45-58.

Ohye, D. F., and W. J. Scott. 1957. Studies in the physiology of *Clostridium botulinum* type E. Austral. J. Biol. Sci. 10:85-94.

Paddon, W. A. 1960. Personal communications.

Parnell, I. W. 1934. Animal parasites of North-East Canada. Canad. Field-Naturalist 48:111-5.

Pauls, F. P. 1960. Personal communications.

Pedersen, H. O. 1955. On type E botulism. J. App. Bact. 18:619-28.

Philip, R. N. 1960. Personal communication.

Prévot, A.-R., and M. Huet. 1951. Existence en France du botulisme humain d'origine pisciaire et de Cl. botulinum E. Bull. de l'Acad. Nat. de Médecine. 135:432-5.

Prévot, A.-R., M. Huet, and A. Thévenard. 1952. Second cas français de botulisme d'origine pisciaire. Bull. de l'Acad. Nat. de Médecine 136:323-4.

Prévot, A.-R., J. Loiseau, and A. Thévenard. 1952. Nouveau cas de botulisme humain d'origine pisciaire. Résultat du traitement par l'anatoxine E. Bull. de l'Acad. Nat. de Médecine 136:663-4.

Prévot, A.-R., and E. R. Brygoo. 1953. Nouvelles recherches sur le botulisme et ces cinq types toxiniques. Ann. Inst. Past. 85:544-75.

Rabeau, E. S. 1959. Botulism in Arctic Alaska. Report of 13 cases with 5 fatalities. Alaska Medicine 1:6-9.

————————1960. Personal communications.

Saito, S., and S. Fujisawa. 1956. Studies on cases of botulism in Akita Prefecture. Epidemiological. Report No. 1. Akita Prefect. Med. J. 8:1-5. (In Japanese).

Skulberg, A. 1958. A case of fish-borne type B botulism. Nord. Hyg. Tidskr. 39:133-6.

————————1960. Personal communications.

Stefánsson, V. 1914. The Stefánsson-Anderson Arctic Expedition: preliminary ethnological report. Anthropol. Papers Am. Mus. Nat. Hist. 14:449.

————————1929. My life with the Eskimo. New York, Macmillan Co. pp.32-3.

Thorborg, N. B., S. Tulinius, and H. Roth. 1948. Trichinosis in Greenland. Acta Path. et Microbiol. Scand. 25:778-94.

Williams, R. B. 1960. Personal communication.

Yamamoto, K. 1960. Personal communication.

Zavadovskaya, T. A. 1940. Typing of a strain of *Bacterium botulinum* isolated from a case of food poisoning. Zhur. mikrobiol. epidem. immunol. No. 4, 59-63. (In Russian).

RECENT RECORDS OF THE CALIFORNIA GREY WHALE (*ESCHRICHTIUS GLAUCUS*) ALONG THE NORTH COAST OF ALASKA

William J. Maher*

THE migratory movements of the California grey whale *(Eschrichtius glaucus)* are better known than those of any other baleen whale. This is because it is the only species that enters shallow waters to calve and because part of its migration route lies close to the shore. Scammon (1874 p. 23), for example, states that these whales "will be seen . . . following the shore so near that they often pass through the kelp near the beach. It is seldom they are seen far out at sea." Its migration is known in considerable detail where it travels along the western coasts of the United States and southern Canada to and from calving grounds in the coastal lagoons of Baja California and adjacent mainland of Mexico. The foregoing comments are based on the works of Scammon (1874), Andrews (1914), Kellogg (1929), and Gilmore (1955, 1958); they are apparently the principal references on the migration of this species.

On its northward movement in the spring the grey whale leaves the coast of North America at the Queen Charlotte Islands. On its return migration in the fall it reaches the coast at Oregon and northern California. Between the time it leaves the coast in April and May until it returns in October and November, records of its occurrence at specific localities are scarce and the extent of its movements in summer are poorly known. The summer range of the Korean population of the grey whale studied by Andrews (1914) is also poorly known.

In the summers of 1953 to 1959 I made some observations of grey whales at several places on the north coast of Alaska. Since previous records from this area are scarce, these observations are reported here.

Known summer range of the grey whale

The summer range of the grey whale has not been well defined. According to Scammon (1874, p. 23) they congregate in the Arctic Ocean and the Okhotsk Sea, but no further details are given. He does, however, describe the primitive whaling methods of the Eskimos, without mentioning

* Museum of Vertebrate Zoology, University of California, Berkeley, California.

the locality at which he became acquainted with them. Because there are Eskimo settlements at East Cape, Siberia, and in Alaska along the east side of the Bering Sea as well as on the shores of the Arctic Ocean, this reference does not help. Andrews (1914, p. 236) says "Information gathered from the whalers tends to show that a large part of the former herd [the Korean population] summers in the Okhotsk Sea and the latter [the California population] in the Bering Sea and farther north." Risting (1928)

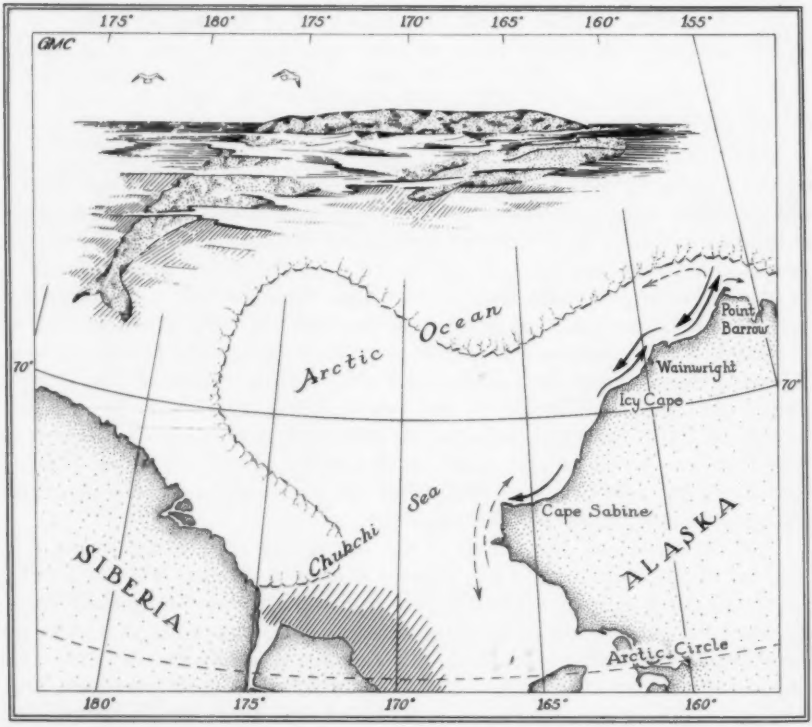


Fig. 1. The localities where grey whales have been observed along the North Alaska coast. The directions of their movements are shown by the heavy arrows. The hatching at the lower left is the range of the grey whale in the Arctic Ocean as indicated by Gilmore (1955, 1958). The approximate mean limit of pack ice in August and September is also shown.

published data on length and sex of 31 grey whales caught off the east coast of Kamchatka between July 27 and August 22, 1925. The most recent publication dealing specifically with the summer range of the grey whale is that of Ichihara (1958). He reports the sighting of three herds of grey whales in the Bering Sea just west of St. Lawrence Island on August 2, 1955. The whales were in groups of 2, 20, and 150, respectively, and were

Table 1. Details of grey whales killed at Wainwright and Barrow.

Locality	*Date*	*Length in feet*	*Remarks*
Barrow	August 10, 1954	25	Calf assoc. with an adult
Wainwright	August 9-15, 1954	25	
Barrow	September 11, 1958	30–35	
Barrow	September 11, 1958	30–35	
Barrow	July 18, 1959	25–28	
Barrow	July 19, 1959	25–28	Calf of the female below
Barrow	July 19, 1959	43	Adult female, lactating
Barrow	September 13, 1959	40–45	Adult female, lactating
Barrow	September 13, 1959	25	Calf of the above female
Barrow	September 13, 1959	25	

traveling west-southwest or southwest. He recorded one other whale moving north in Unimak Pass in the southern Bering Sea on May 29, 1957. Ichihara also cites the work of Sleptsov, who has summarized the range of the grey whale along the Siberian coast. According to Sleptsov, the grey whales arrive in Siberian waters in the Bering Sea in late May and early June. They usually stay in the Bering Strait and along the coast of the Chukchi Sea in summer. They range south along the Siberian coast to the Olyutorsky Gulf but no longer as far as Kamchatka. This is essentially the distribution indicated by Gilmore (1958) in his most recent map of the distribution of the grey whale.

According to Mizue (1951), the Korean population of the grey whale is confined to the Okhotsk Sea in the summer and there is no intermingling with the California population at present. This paper, then, will be concerned with the northern extent of the range of the California population.

Records from northern Alaska

The first published record that I have found on the grey whale being sighted in the Arctic Ocean along the north coast of Alaska is that of Bailey and Hendee (1926) who saw "one or two" at Wainwright in the summer of 1924. Bee and Hall (1956) attribute to P. Sovalik the statement that the grey whale is "occasionally taken or seen" at Barrow. On August 10, 1954, a whale was killed at Barrow. I was present when the animal was butchered and identified it as a grey whale. Hurley and Mohr (1957) described a new species of whale louse from a large series of lice collected from this specimen. Their paper thus contains the first specific record of the grey whale being killed in northern Alaska.

Nine grey whales have been killed by the Eskimos at Barrow and Wainwright subsequent to the one cited above. Table 1 lists all kills with the available data. The length of most whales was estimated by various informants who saw the animals butchered. The length of the largest whale killed in July 1959 was determined by pacing.

It is evident from the lengths of the whales killed that the Eskimos mostly take juvenile animals. The grey whale is born in the winter months. The young are 15 to 17 feet long at birth according to Risting (1928). Mizue (1951) gives the length of the Korean grey whale at birth as 15 to 16 feet. Growth is rapid. The young whale doubles its length in one year so that by the following winter the yearlings are approximately 30 feet long. In late July and August they are between 25 and 30 feet in length (Risting, 1928).

According to these criteria most whales listed in Table 1 were born the previous winter. This is certainly true of the whale taken on August 10, 1954, that I estimated to be 25 feet long and was accompanied by its mother. The female was shot at but could not be killed. The two whales taken on July 19, 1959 were an adult female and its calf; the one killed on the previous day was also a calf. Those taken on September 11, 1958 (Fig. 2) may also have been juvenile, though the estimated length of 30 to 35 feet is a little too great for that age class. An adult female and two calves were shot on September 13, 1959. It was reported that milk was running from the female's nipples when she was pulled on to the beach. One of the calves was believed to be hers.

Five skulls found on the beach near Barrow Village were measured. The largest was 108 by 49 inches. The remaining four were considerably smaller, their lengths ranged from 62 to 65 inches, and the widths from 30 to 33 inches.

The dates on which these whales were taken range from July 18 to September 13. This is essentially the average period in which the coast at Barrow is free of ice.

Movements

There are several observations of the grey whale along the coast of northern Alaska. On August 9 and 10, 1953 I observed between 50 and 100 grey whales from the beach at Wainwright. All were moving in a southwesterly direction and one or two were in sight at any time during both days. No detailed notes were taken. Hahn observed a passage of the grey whale at Wainwright on July 5, 1954. He says *(in litt.)* that a large number went by "right after the ice went out. We watched them go by all day . . . These whales were definitely on the move, also, because we watched them come from the south and disappear in the north. [They were traveling] about a half mile to a mile off of the beach, sometimes closer and sometimes farther." I observed one playing in heavy surf off Point Barrow in August, 1954. A few whales were seen passing Cape Sabine, 30 miles east of Cape Lisburne, from August 3 to 5, 1959 heading southwest. On the evening of August 5 a group of them were feeding off the mouth of the Pitmegea River at the Cape. This group consisted of at least three calves with their mothers, and four to six other adults. They were dispersed along the coast for one mile east of the mouth of the river and were gone the following day.

From these data, as well as from information obtained from Eskimos, the following outline of the occurrence of the grey whale along the north coast of Alaska is suggested (see map). A brief description of ice conditions along the coast will clarify the following discussion. In the winter the Arctic Ocean is almost completely covered with ice, which extends over the northern one-third of the Bering Sea south to latitude 60° N. However, there is usually a break or lead between the pack ice and shore-fast ice which runs parallel to the coast and at Wainwright and Barrow lies a few miles from shore. Movements of the pack ice open the lead periodically, but during the coldest months the water freezes over within hours, so that there is little open water except that which is exposed briefly by the constantly shifting masses of ice. When the weather moderates in the spring,

Photo: Stephen Nathanson

Fig. 2. Young California grey whale killed near Barrow Village, September 11, 1958.

the water no longer freezes quickly, and the current that sweeps along this coast from the Bering Strait becomes stronger; "like a river" according to the Eskimos. These two factors keep the lead open more or less continuously. At the same time the southern limit of the pack ice is retreating to the north. By late June and early July there is open water in the southern part of the Chukchi Sea just north of Bering Strait. This extends northeast along the Alaskan coast to Icy Cape, from where the narrow lead continues along the shore to Barrow and beyond to the east. The grey whales probably enter the Arctic Ocean in the middle of June. Nikulin (1946) reports that they appear at this time in Bering Strait. The bowheads *(Balaena mysticetus)* have already migrated along the lead and reached Barrow in mid-April. The grey whales move along the same route and reach Wainwright and Barrow in the later part of June and early July. By this time the shorefast ice is rotten and the Eskimos have ended their spring whaling. In late July, August, and September, the Arctic Ocean is usually free of ice to latitude 70 to 73° N. The coast is then ice-free all the way to Barrow. East of Barrow a narrow coastal strip of water is usually free of ice, but in general the ice tends to remain close to this section of the coast during the entire summer.

Grey whales are seen near shore in summer by the Eskimos from Barrow west to Icy Cape, and are considered common along this part of the coast. Those seen near Barrow appear to be settled. They are scarce along the coast east of Barrow. Pete Sovalik reports seeing them at Flaxman Island, the mouth of the Shaviovik River, Foggy Island, and Beechy Point. They are also seen at Barter Island according to Vincent Nagiak.

It thus appears that the bulk of the population remains in the waters westward of Barrow feeding and moving about at random during the summer. Comparatively few disperse to the east. It is not known how far from shore the whales move; part of the population may actually stay close to the edge of the ice pack as it moves off shore. Certainly, if the bulk of them remained close inshore, sight records of them would be more frequent than they are.

Beginning in early August they are again seen moving southwest along the coast west of Barrow in what seems to be a purposeful manner. Judging by the dates of the kills given above, the dates of their departure are not well defined. Thus, some were still in the vicinity of Barrow in mid-September in 1959. There is probably considerable variation in their migration as a result of the different movements of the pack ice from year to year. According to Nikulin (1946) they remain in the waters of Bering Strait until October.

Discussion

The lack of records of the grey whale from northern Alaska is puzzling in view of the fact that they have probably always been there. The animal is known to the present natives who say that they have been taking occasional individuals on an average of one every 5 or 6 years. Whaling

ships were in these waters from the middle of the 19th century until the first decade of the 20th century. Townsend (1928) plotted the positions of bowhead whales killed by some of these whalers. He has records of whales taken all along the coast during July, August and September. In his paper Townsend has listed the number of each species of whale taken by the ships whose logbooks he examined. He records 557 grey whales in a total of 53,877 entries. Unfortunately he was not concerned with the grey whale and did not plot the localities of these catches. A check of the total catch of the ships that took grey whales show that many of them had also taken bowheads. The bowhead is the most northern of the baleen whales. The 5,114 kills plotted by Townsend were taken in the northern Okhotsk Sea, Bering Sea, and the Arctic Ocean. The fact that both species were taken on the same voyage by some ships suggests that some grey whales may have been taken in these northern waters. Most, however, were probably taken in temperate latitudes in the winter months. Scammon points out (1874, p. 31) that "in those far northern regions, the animals are rarely pursued by the whale-ship's boats: hence they rest in some degree of security." It may be, therefore, that the species was common in the Arctic Ocean but that it was largely ignored by whalers.

Only three instances of the grey whale having been taken along this coast in former years are known to me. According to the Eskimos a grey whale was killed at Cross Island in 1933, and two were taken at Wainwright by Jim Allen, the local trader in 1934.

Eskimos often hunt the grey whale with rifles rather than with the old brass shoulder and darting guns that they use in the spring whaling for the bowhead. The reason why mainly juvenile grey whales are taken seems to be that the guns used are not powerful enough to kill adult whales in most instances.

There is evidence that indicates that the grey whale does little or no feeding while migrating, or in its winter breeding grounds (Scammon 1874, Andrews 1914). Most authorities have commented on the habit of this species of remaining close to shore and of entering shallow water. All observations that indicate this, however, refer to the species on migration or in its breeding grounds. Their food habits in the summer are poorly known. Evidence that would indicate that they feed in shallow water while they are in the arctic is not conclusive. Zenkovitch (cited in MacKintosh 1946) found that they were feeding on bottom-living amphipods. Nikulin (1946) says that they often enter bays and lagoons. My own observation of a group feeding at the mouth of the Pitmegea River indicates that they feed in shoal water in some instances. However, it is uncertain if these bottom-dwelling amphipods do constitute an important item of diet. Howell and Huey (1930) examined the stomach of a grey whale taken off the coast of northern California in July, 1926 and found that it contained the shrimp *Euphausia pacifica*. Though this whale was far south of its usual summer range, the fact that it was taking krill supports Gilmore's (1958) suggestion that they feed on large plankton, especially euphausid shrimps.

Scammon (1874) refers to the grey whale forcing its way among the floes in the Arctic Ocean and Okhotsk Sea, and he reproduced a dramatic picture (plate 5, p. 32) of a herd of them among the loose floes at the edge of the pack ice. It is possible that this animal is much more closely associated with arctic ice than has been assumed, and that it does not necessarily feed exclusively or even predominantly in shallow water.

Acknowledgments

Peter Hahn, a school teacher of the Alaska Native Service at Wainwright supplied information on the grey whale killed at that village in 1954 and also other observations on the occurrence of the species in that locality. Max C. Brewer, Director of the Arctic Research Laboratory at Barrow, Paul Teitjen, Richard T. Holmes, Henry E. Childs, Jr., and Tom Sovalik supplied me with information on some of the whales taken at Barrow; Pete Sovalik gave general information on the occurrence of this species along the northern Alaskan coast. I wish to express my gratitude to these persons.

I especially wish to thank Frank A. Pitelka and Seth B. Benson, who read the manuscript and offered many helpful suggestions.

My observations in 1953, and 1956 to 1959, were made while I was engaged on projects sponsored by the Arctic Institute of North America under contract to the Office of Naval Research. The observations made in 1954 and 1955 were made while I was employed by the U. S. Geological Survey. The assistance of these agencies is gratefully acknowledged.

Gene M. Christman, staff artist of the Museum of Vertebrate Zoology, drew the map.

This report was written during the tenure of a Predoctoral Fellowship from the National Institute of Allergy and Infectious Diseases, United States Public Health Service.

References

Andrews, R. C. 1914. Monographs of the Pacific Cetacea. I. The California gray whale (*Rachianectes glaucus* Cope). Mem. Am. Mus. Nat. Hist., n. s. 1:227-287.

Bailey, A. M., and R. W. Hendee. 1926. Notes on the mammals of northwestern Alaska. J. Mamm., 7:9-28.

Bee, James W., and E. R. Hall. 1956. Mammals of northern Alaska on the arctic slope. Univ. Kansas Mus. Nat. Hist. Misc. Pub. No. 8, 309 pp.

Gilmore, R. M., and G. Ewing. 1954. Calving of the California gray whales. Pac. Disc., 7:13-15, 30.

Gilmore, R. M. 1955. The return of the gray whale. Sci. Am. 192:62-67.

———————1958. The story of the gray whale. Privately printed. San Diego. 16 pp.

Howell, A. B., and L. M. Huey. 1930. Food of the gray and other whales. J. Mamm., 11:321-322.

Hurley, D. E., and J. L. Mohr. 1957. On whale lice (Amphipida: Cyamidae) from the California gray whale, *Eschrichtius glaucus*. J. Parasit., 43:352-7.

Ichihara, T. 1958. Gray whales observed in the Bering Sea. Sci. Rep. Whales Res. Inst., 13:201-205.

Kellogg, R. 1929. What is known of the migrations of some of the whalebone whales. Smithsonian Rept., 1928:467-494.

Mizue, K. 1951. Gray whales in the east sea area of Korea. Sci. Rep. Whales Res. Inst., 5:71-79.

MacKintosh, N. A. 1946. The natural history of whalebone whales. Smithsonian Rep., 1946:235-264.

Nikulin, P. G. 1946. About the distribution of whales in seas surrounding the Chukotka Peninsula. Tikhookeanski nauchno-issledov. inst. rybnogo khoz. i okeanogr. Izvestiya, 22:255-7. (In Russian).

Risting, S. 1928. Whales and whale foetuses. Statistics and catch measurements collected from the Norwegian Whalers Association. Rapp. Cons. Expl. Mer., 50:1-122.

Scammon, C. M. 1874. The marine mammals of the north-western coast of North America. New York: G. P. Putnam's Sons, 320 pp.

Townsend, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica, 19:1-50.

NOTES

SOME SOIL FUNGI FROM AN ALASKAN TUNDRA AREA.

Very little is known of the populations of organisms occurring in soils and surface waters in North America north of the 60th parallel. From work done in Europe it may be assumed that several types of fungal populations occupy such habitats. Féher[1] compared soils from as far north as 69°30′ in Lappland with those from as far south as Hungary. He found at least 39 species of soil fungi in the more northern samples and showed that bacteria occur also throughout this area, but that the numbers of bacterial colonies declined toward the north more rapidly than the numbers of fungal colonies, giving higher fungus to bacterium ratios as northern latitudes were approached.

Verbal reports by students of northern biotas indicate a fairly complex population of fleshy fungi in the tundra-covered regions of North America. Savile[2] reported on the occurrence of 28 species of fleshy and plant-parasitic fungi on Somerset Island, District of Franklin, in the middle of the Canadian Arctic Archipelago; although this island lies between 72° and 74°N. and is treeless many of the species reported are widespread in more southern regions. Kelsall[3] has noted the occurrence of a poisonous mushroom north of the tree-line in the Northwest Territories. Favre[4] reported on a 15-year survey of those soil fungi that produce fleshy fruit bodies and that occur above timberline in the Swiss Alps. He suggested, on the basis of comparison between alpine and tundra populations, that the fungi could live in both types of habitats and that a large percentage of these species formed mycorrhizae in association with low-growing woody plants common to both areas.

The following report is based on samples of soil and water collected in a tundra area and is restricted to a listing of certain soil moulds found there.

In August and September 1957 and June 1958 the junior author collected a series of water and soil samples from which a number of mould and yeast cultures were isolated. The samples were obtained while making a survey of enteric infections among the Eskimos of Southwestern Alaska. Specifically, sampling was carried out within a 6-mile radius of the Eskimo village of Napaskiak, about 400 miles west of Anchorage, near the head of Kuskokwim Bay.

A good description of the area in which the sampling was done was presented by Williamson[5]. The region lies in the ecotone between the forest and tundra regions, and the sampling was carried out in areas described as "wet tundra" and "heath tundra". In this region the average annual precipitation is 19 inches, the climate approaches the marine type, with a mean annual temperature of 30°F., a monthly mean for July of 55°F. and for January of 6°F., and an average growing season of 102 days. With the climate as much cool-maritime as arctic, the soil fungi are probably low-temperature species adapted to a cold environment. The article by Williamson is illustrated by maps and photographs giving the geographic location and illustrating environmental conditions.

In August 1957 five pond and three soil samples were collected for a preliminary investigation into the microorganisms of this area. In September 1957 six soil and pond samples, including four (Nos. 1-4) from the permafrost area on the west side of the Kuskokwim River, were collected and in June 1958

Table 1. Temperature and pH values of tundra ponds, and soils.

Date of collection	*Sample number*	*Pond*		*Soil*	
		Temperature °C	*pH†*	*Temperature °C*	*pH†*
August, 1957	1	15.5			
	2	12.5	7.02		6.53
	3	14.5	7.13		
	4	10.5	7.28	5.5	6.52
	5	12.0	7.50	5.5	6.52
September, 1957	1				
	2		7.37		5.72
	3		7.23		4.83
	4		7.28		6.07
	5		7.37		6.60
	6		7.08		4.51
			6.92		4.98
June, 1958	1	12.5	7.28		7.07
	2	12.0	6.65		5.83
	3	11.0	6.48		4.50
	4	12.5	6.28		4.58
	5	12.0	6.73		5.58
	6	13.0	6.88	8.5	5.93
	7	12.5	6.79	1.0*	5.68
	8	12.5	6.53	0.5*	5.24
	9	12.5	6.51	0.5*	5.21
	10	12.0	6.02	0.0*	4.41

* Temperature taken at frost level after clearing away surface vegetation.
† pH readings made with Beckman meter Model G.

ten samples of soil and pond water. Soil samples taken near ponds were assigned the number of the pond. Soil and water samples were plated in BBL Rose-Bengal Agar containing aureomycin. Plates were incubated in the field at 20°C. for 4 to 5 days when counts were made and isolates transferred to tryptone-glucose-extract agar slants. Table 1 gives the temperatures and pH levels of the ponds and soils from which samples were taken.

Pond samples were taken from near the surface of ponds whose waters were low in minerals and high in humic colloids. Soil samples were taken 6 to 12 inches below the surface in bog-type soils with a tough fibrous brownish mat on the surface and a dark-colored, humus-rich soil underneath. In general the samples ranged from acid to neutral in reaction, pH of the water samples varying from 6.02 to 7.50 and from 4.41 to 7.07 for the soils.

Plate counts of moulds were made on most water and soil samples. As shown in Table 2, pond samples had considerably smaller counts than soil samples on the basis of volume of original sample tested. Yeasts were more sporadic in occurrence than moulds, and counts were not made of these colonies. Table 2 shows that mould counts from pond water samples ranged from less than 1 to 20 per ml, with an average of 6 per ml. Soil samples yielded a range of colonies from 320 to 2,200,000 per ml. The median, 14,000 colonies per ml, is probably a more accurate estimate of the mould populations of these soils than the average of the 17 samples reported.

Isolates on tryptone-glucose-extract agar slants were shipped by air mail to Cincinnati where they were transferred to stock culture slants of neopeptone-dextrose agar, on which they have been maintained to date.

The following fungi were found among these isolates. They include range extensions for most species, since little if any work has been done on the fungi of the soils of Alaska, especially those tundra soils located west of the fertile or glacial coastal valleys of southeastern Alaska (Cash[6]; Cooke and Lawrence[7]; Sprague[8]; Sprague and Lawrence[9]).

PHYCOMYCETES. **Mucoraceae.**

Mortierella isabellina (Oudemans) Zycha. Soil sample No. 5, September 1957 (30).

Mucor angulisporus Naumov. Pond water, August 1957 (62b); Soil No. 1 (12), and No. 10 (87, 90), June 1958.

Mucor corticolus Hagem. Soil No. 1, June 1958 (63c).

Mucor hiemalis Wehmer. Soil No. 4, September 1957 (24); Pond 5 (52) and 10 (59), Soil No. 8 (79), June 1958.

FUNGI IMPERFECTI. **Moniliaceae.**

Botrytis terrestris Jensen. A culture tentatively assigned to this species was isolated from soil at Station No. 8 in June 1958 (82).

Penicillium expansum (Link) Thom. Isolated from Soil No. 9, June 1958 (84).

Penicillium implicatum Biourge. This species of *Penicillium* occurred on several occasions and was isolated from Pond No. 4 (17) and Soil No. 1 (20) and 4 (23), in September 1957; and from Soil No. 4 (69); 8 (80) and 10 (88), in June 1958.

Penicillium raistrickii G. Smith. Isolated from Soils No. 2 (64) and 10 (89), June 1958.

Penicillium spp. It is difficult to get isolates of *Penicillium* in pure culture upon preliminary isolation. Isolates from Ponds No. 1 and 2, September 1957; Ponds No. 3, 4, and 7 and Soil No. 9, including culture numbers 13, 14, 40, 42, 46, 55 and 83, have not yet been identified to species.

Sporotrichum epigaeum Brunard var. *terrestre* Daszewska. Two isolates from soil Area No. 7, June 1958 (73, 74a), are tentatively assigned to this species. In appearance they are similar to the one listed under *Botrytis* above but they are pure white with hyaline spores.

Trichoderma viride Pers. ex Fr. Isolated from Pond No. 3, September 1957 (15, 16), and Soil No. 2, June 1958 (63a). It is interesting that at room temperature on rich culture media the four isolates from southwestern Alaska should revert to an almost completely mycelial condition. At the present time (Feb. 1960) only one of the four isolates resembles a *Thichoderma* culture, while in the early summer of 1958 all four were typical green cultures of *Trichoderma*.

Moniliaceae spp. In all isolation work based on soil and water samples a certain number of cultures remain anonymous since they do not sporulate under laboratory conditions. Cultures from the following habitats fall in this category: the soil samples in August 1957; Pond No. 5; Soil No. 2, September 1957; Ponds No. 2, 3, 4, 5, 10; Soils No. 2, 6, 8, and 9, June 1958; (5, 18, 21, 36, 41, 45, 51, 60, 61b, 63b, 65, 73, 76a, 81, 82, 85, 86).

Dematiaceae.

Cladosporium cladosporioides (Fres.) deVries. Isolated from Soil No. 4 (68) and No. 6 (76b), June 1958.

Dematiaceae spp. Three cultures, assignable to species within this family should they sporulate at a later date, are reported: Isolated from Ponds No. 2 and 3, June 1958 (38a, 43, 44a).

Tuberculariaceae.

Fusarium oxysporum Schlech. em. Snyder and Hansen. A strain, tentatively assigned to this species, was isolated from Pond No. 5, September 1957 (19).

Phomaceae.

Phoma terrestris H. N. Hansen. Cultures of *Phoma* isolated from soil or water samples have to be filed immediately with the unidentifiable species or strains in a culture collection unless a definite host relationship can be established. The original description of this species allows a wide degree of latitude in making identifications of soil isolates. Within the series of cultures tested for pathogenicity on onions, one host of this species, there is a wide degree of culture types ranging from lack of aerial mycelium to an abundance of such a mycelium. The pycnidia in the two cultures assigned to this species are

Table 2. Mold plate counts, in colonies per ml.-sample.

Date of collection	*Sample number*	*Number of colonies*	
		Pond	*Soil*
August, 1957	5	5	4,000
September, 1957	1	3	3,100
	2	6	9,400
	3	11	4,000
	4	2	15,000
	5	20	48,000
	6	1	34,000
June, 1958	1	10	60,000
	2	16	28,000
	3	10	200,000
	4	18	66,000
	5	1	14,000
	6	1	3,000
	7	1	1,600
	8	1	320
	9	1	2,200,000
	10	1	5,800

thick walled, embedded in a dense grey to brown mycelium, and produce hyaline bacillar pycnidia-spores 5.5 x 2 μ. Isolated from pond water collected in August 1957 (9), and from water from Pond No. 7, June 1958 (56).

Phoma spp. Two cultures which differ from each other, contain pycnidia-like structures which are black, thick walled, and embedded in a dark brown mycelium. No spores had been produced on either strain after 2½ months. Isolated from Ponds No. 2 (38b) and 4 (47), June 1958.

Cultures isolated from water in Pond No. 6, and from Soils No. 1, 3, 6, and 7, did not produce growth at Cincinnati or grew so slowly that no attempt was made to reach a decision as to their identification. It is quite possible that among these cultures are species adapted to low-temperature habitats (54, 61a, 62a, 66, 75, 77).

One isolate of the red yeast *Rhodotorula glutinis* (in the broad sense) was obtained from pond water in August 1957 (10); and 11 isolates (25, 26, 27, 28, 29, 48, 49, 50, 53, 71, 72) of white yeasts were made from water in Ponds No. 3 and 5, and Soils No. 1 and 3, September 1957; and from water from Ponds No. 4 and 6, and from Soil No. 4, June 1958. Identifications of these yeasts are incomplete.

Assistance in identification of cultures has been furnished for Mucoraceae by C. W. Hesseltine, Peoria, Illinois; for *Penicillium* by Dorothy Fennell, Natick, Massachusetts; and for Heasts by H. J. Phaff, Davis, California. Numerals in parentheses are AHRC culture numbers assigned to the strains isolated.

This set of isolations from soil and water samples from tundra habitats indicates that even in the presence of permafrost the fungi take an active part in the degradation of organic matter deposited by the higher plants, lichens, and Bryophytes in the surface layers that thaw during the brief summer. That this should be true is not surprising in view of Féher's work with soil organisms. In 1933 he reported isolating from soil samples obtained from 66° 50′N. to 69° 30′N. In Europe 39 species of soil fungi including some species and all genera listed above. There seems to be no doubt that, with refinement of techniques and development of specific interests, other species can be added to the list.

WM. BRIDGE COOKE
H. T. FOURNELLE

[1]Féher, D., 1933. Untersuchungen über die Mikrobiologie des Waldbodens. Berlin: Julius Springer.

[2]Savile, D. B. O., 1959. The botany of Somerset Island, District of Franklin. Can. J. Bot. 37:959-1002.

[3]Kelsall, J. P., 1959. A poisonous fungus in the Northwest Territories. Can. Field. Nat. 73:130.

[4]Favre, J., 1955. Les champignons supérieurs de la zone alpine du Parc National Suisse. Part 5, N.S. 33:1-212.

[5]Williamson, E. S. L., 1957. Ecological distribution of birds in the Napaskiak area of the Kaskokwim River Delta, Alaska. The Condor 59:317-338.

[6]Cash, Edith, 1953. Fungi of Alaska. Pl. Dis. Reptr., Suppl., 219:1-70.

[7]Cooke, W. B., and D. B. Lawrence, 1959. Soil mold fungi isolated from recently glaciated soils in Southeastern Alaska. Jour. Ecol. 47:529-549.

[8]Sprague, R., 1955. Check list of the fungi of the Glacier Bay National Monument, Alaska. Washington State College Research Studies, Pullman, 23:202-224.

[9]Sprague, R., and D. B. Lawrence, 1959, 1960. The fungi on deglaciated terrain of known age. Washington State University Research Studies, Pullman. 27:111-128, 224-229; 28: (in press).

Application for the position of Executive Director of the Boreal Institute of the University of Alberta.

The Boreal Institute invites applications for the above position.

The Executive Director will be a full-time appointee who will aid the Directorate in planning the activities of the Institute, implement its decisions, administer its daily operations, solicit funds for its advancement and publicize its activities and accomplishments.

Applicants must be interested in the North, have administrative ability, ability to deal with the public and be fluent in written and spoken English. They should be willing and able to travel in the North and have some northern experience.

Applications must include a complete account of experience and educational background, references, other pertinent data, and a recent photograph.

The appointment will be effective April 1, 1961. Salary will depend upon qualifications. Applications should reach the Boreal Institute, University of Alberta, Edmonton, Alberta, Canada, before February 1, 1961. They will be held in confidence if desired.

INSTITUTE NEWS

The Arctic Institute Devon Island Expedition 1960.

The Arctic Institute of North America, having decided that scientific research in the Arctic could be significantly advanced by establishing permanent base facilities at certain key localities and conducting long term, detailed, integrated observations in several scientific fields, initiated the Devon Island Expedition 1960-1963, the objectives of which are:

(1) A study of the relationships between the marine environment (Jones Sound), the Devon Island Ice Cap, and the atmosphere, with special regard to heat budget, energy flow, and moisture transfer.

(2) A detailed investigation of the oceanography and marine biology of Jones Sound.

(3) A detailed investigation of the archaeology, biology, and geology of Devon Island, together with other studies that may provide auxiliary information for objective (1).

The main purpose of the 1960 expedition was to establish facilities and cache

supplies to support the scientific program beginning in 1961. The party consisted of the following: S. Apollonio, leader; V. D. Boyd, master mechanic; B. D. Clarke, tractor specialist; C. R. Harington, naturalist and general assistant; G. R. Lowther, archaeologist; R. S. McCall, archaeological assistant; D. R. Oliver, zoologist and general assistant; G. E. Stewart, Weasel specialist.

The party left Quebec City on July 31 on board C.M.S. *d'Iberville* and arrived off Cape Skogn, Devon Island on August 20. By August 24 a camp consisting of three prefabricated Jamesway buildings and stores for twenty people for 5 months was installed at 75°42′N. 84°26′W.

An 18-mile tractor route to the edge of the ice cap was then laid out and 6 tons of ice cap station supplies were hauled to the top of a 1000-foot plateau at the beginning of that route. The top of the plateau, the only practicable route to the ice cap, was found to be thawed to such an extent that the tractors became mired to the axles. It was decided to cache the supplies at the edge of the plateau and to establish the ice cap station in the spring of 1961, when the ground will be frozen.

On September 6, Apollonio, Harington, and Stewart examined the ice cap margin and found that it is readily accessible to tracked vehicles. The base camp, the power boat, the two diesel tractors, and the two Weasels were then secured for the winter.

The party were picked up by helicopter of the U.S. icebreaker *Westwind* and taken to Thule, Greenland, from where they flew on a USAF MATS flight to New Jersey and returned to Montreal on September 16.

The archaeologists located two previously unknown sites. The first, in the vicinity of the base camp, includes four or five houses, three temporary houses, and several caches. It is probably a late Thule site.

The second site is located near the western tip of Cape Sparbo and has been tentatively named the "Inapok" site. It was studied by Lowther, McCall, and Oliver from August 26 to August 31 and includes 9 houses, tent rings, and a number of other structures. There are undoubtedly both Dorset and Thule, and perhaps pre-Dorset elements in the site. The entire site is well preserved and has yielded about 90 artifacts including Dorset blades, microblade points, burins, microburins, burin spalls, knives, and end blades.

Oliver continued his study of arctic chironomids and other aquatic insects by extensive collecting at Resolute and on Devon Island. Harington measured over 60 musk ox skulls and made a comprehensive plant collection.

The Devon Island Station will be reoccupied in late April 1961, at which time the ice cap station will be established. Studies in meteorology, glaciology, oceanography, marine biology, and geology will then begin. The archaeological work will continue with a detailed excavation of the "Inapok" site and further reconnaissance of the island.

SPENCER APOLLONIO

Ellesmere Island Ice Shelf Project 1960

During 1960 the Arctic Institute of North America continued the studies in Ellesmere Island that were begun in 1959 under contract to the Terrestrial Sciences Laboratory of Air Force Cambridge Research Center of the U.S. Air Force. The Defence Research Board of Canada had an observer with the party, and the Institute cooperated in the field with groups from Dartmouth College, Hanover, N.H. and the U.S. Naval Civil Engineering Laboratory. Twenty-three persons were actively engaged in field work between April 26 and September 24, 1960, but only seven men remained on the Ice Shelf throughout the season — Dr. Lister, R. B. Sagar, R. L. Lenton, F. Layman, J. Mulholm, I. Spokas, and R. Grant. Dr. G. Rigsby was in charge of the overall program for the Institute, and Dr. H. F. Lister was the Field Leader. Personnel and supplies were airlifted by a turbo jet C130 Hercules under the command of Captain G. Khourie.

The main program was an evaluation of the mass balance of the Ward Hunt Ice Shelf and Ice Rise. A survey line from the mainland to the edge of the Ice

Shelf, established in 1959 was resurveyed. R. W. Mason and his team installed a grid of markers for an aerial survey, but unfortunately the Royal Canadian Air Force Air Photography Wing was unable to make the necessary flights on account of poor weather conditions. General climatic observations and detailed micrometeorological studies were made on the Ice Shelf and Ice Rise by Lister and Sagar. In addition, level lines were run across the Ice Shelf, a 30-day tidal record was kept at the Shelf edge, and ablation/accumulation measurements made over a grid of 70 stakes. R. Ragle of Dartmouth College directed the coring of some deep holes in the ice of both the Ice Shelf and the Ice Rise at four locations. The cores obtained were flown out to Dartmouth College for fabric analysis. A detailed geomorphological study of the coast of Ellesmere Island opposite Ward Hunt Island and of Ward Hunt Island was made by Dr. J. Lyons. The N.C.E.L. party under D. E. Well conducted studies of the ice surface with special attention to factors affecting suitability for aircraft landings.

Although few quantitative results of the work are available as yet, snow accumulation was found to be more than 50 per cent greater than in a comparable period in 1959. The summer of 1960 was relatively warm, but the net loss of the ice by melting and run-off only equalled that of 1959. There is some indication that the radiation regime of the area controls the amount of summer melt. The results of ice core analysis and the geomorphological studies may help to throw some light on the history of the Ice Shelf, and the combined studies are intended to evaluate the critical conditions that govern the growth and break-up of shelf ice in the region.

R. B. SAGAR

Missing field party on Great Bear Lake

Miss Annemarie Kröger and Miss Joan Goodfellow were reported missing during July while working on Smith Arm of Great Bear Lake. They had been making a geomorphological study of the region with special attention to the raised beaches of the area and the glacial history. It was the second season on the lake for Kröger and the work this year was jointly sponsored by the Arctic Institute of North America and the Geographical Branch of the Department of Mines and Technical Surveys, Canada.

Alarm was raised when a pilot of Mackenzie Airways failed to contact the women when flying-in supplies to a prearranged cache. On July 18 the Royal Canadian Mounted Police in a chartered aircraft discovered their overturned canoe with outboard motor and two life jackets in Good Hope Bay. R.C.M.P. aircraft then searched both shores of Smith Arm, and in nearly 80 hours of flying a quantity of jerry-cans and camping gear was recovered, together with a note left by the pair at their last main camp on July 8. There was no trace of the missing women.

A ground party was landed by the salvaged canoe on the morning of July 29 and the entire northern shore was examined on foot or from the canoe, with the hope of discovering traces of survivors from an accident. Although this search led to the discovery of more minor debris it did not reveal any traces of the party west of their last established camp, and from all the evidence it would seem that both women drowned when their canoe upset near the mouth of the Katseyedie River. The ground search was discontinued on the night of August 6, but R.C.M.P. aircraft frequently searched Smith Arm until freeze-up without results.

Annemarie Kröger was a Canadian citizen working as a Research Associate at McGill University, Montreal, but came originally from Hamburg, Germany. Joan Goodfellow was from Plaster Rock, New Brunswick, and was to have joined the Geographical Branch after the expedition.

Gifts to the Library

The Institute Library acknowledges with thanks gifts of books and reprints from the following persons and organizations:

T. J. Cade
F. A. Cook

D. L. Dineley
Moira Dunbar
N. Dwyer
D. V. Ellis
B. Fristrup
R. N. Harvey
J. D. Ives
I. A. McLaren
L. F. MacRae
R. L. Monahan
S. Orvig
G. R. Parkin
F. Ridley
L. Rivard
O. Svarlien
C. W. Thomas
B. A. Tikhomirov
I. Whitaker
American Museum of Natural History
Canada Defence Research Board
Canada Defence Research Board. Scientific Information Service
Canada Department of Mines and Technical Surveys
Canada Department of Mines and Technical Surveys. Geographical Branch
Canada National Research Council. Library
Greenland. Landslaegen
Harvard University. Gray Herbarium
Hudson's Bay Record Society
Japan. Ministry of Education. Antarctic Office
Scott Polar Research Institute

Technical Papers of the Arctic Institute

No. 5 of this series, MARINE INFAUNAL BENTHOS IN ARCTIC NORTH AMERICA. By Derek V. Ellis, 53 pages, 2 plates, 17 figures, and 9 tables, has appeared. Copies can be obtained from the Montreal Office at the price of $1.00 to members, $2.00 to non-members.

REVIEWS

A PHOTO-RECONNAISSANCE SURVEY OF LABRADOR-UNGAVA

By F. KENNETH HARE. *Geographical Branch, Department of Mines and Technical Surveys. Memoir 6, 83 pages, 5 tables, 2 maps in text, 2 folding maps, 2 maps with overlays in pocket. 9¾ x 6½ inches. Ottawa: The Queen's Printer. 1959. $2.00.*

The appearance of this memoir is of considerable importance to the botanist working in Canada, and this review will be concerned primarily with the botanical content of the work. Not only does the paper make available the first balanced and accurate map of the vegetation of a large portion of northern Canada, but it demonstrates the value of applying certain survey methods in the study of Canadian plant communities. Among professional botanists in Canada there is remarkably little apparent interest in compiling accurate vegetation maps, although it is widely recognised, especially in the Old World, that such a step is the soundest beginning to the study of vegetation. That this first accurate map of vegetation should be the work of a group of geographers rather than botanists further emphasizes the neglected condition of geobotany in Canadian institutions.

The most useful lesson in this work for the botanist is that reconnaissance surveys on extensive scales must be made if we are to establish properly, and with any degree of objectivity, the general background for more detailed, intensive studies. Professor Hare makes clear in his Introduction the regrettable, even embarrassing truth that much of our knowledge of Canadian vegetation beyond, and often within the regions of merchantable timber is superficial and fragmentary. For example, it is evident that much of the

confusion and error that characterizes many North American contributions to Quaternary and Recent vegetation history can be traced to an incomplete knowledge and understanding of the contemporary vegetation and flora of northern regions. Professor Hare has filled a large gap in our knowledge, and has provided the incentive and direction for detailed botanical studies of many kinds. He groups the vegetation of Labrador-Ungava into a small number of simple types, but it will be many years before the whole area is mapped in greater detail and with the consistency of treatment that is one of the advantages of the photo-survey method.

My chief regret about this publication is that it was found necessary, or desirable to reduce the scale of the vegetation map from 1: 1,000,000 to 1: 4,000,000 — the latter is described as "a scale suitable for inspection and publication". The original mapping was at 1: 500,000, the information having been transferred from vertical air photographs at scales between 1: 40,000 and 1: 60,000, and it is suggested that the publication of the 1: 1,000,000 maps would have justified any increased cost by making available greater detail than is shown on the map. It is rather paradoxical that at the other side of the continent we have a recently published vegetation map of Alaska and Yukon, which is little more than a very simple zonal map, printed at the unnecessarily large scale of 1: 2,500,000 and with a wealth of topographical detail. Professor Hare and his colleagues have accumulated enough information with adequate accuracy to merit printed maps at 1: 1,000,000.

It will be salutory to botanists to find an investigation of vegetation that is confined to the reporting of factual data, without imposing any set of subjective notions about community dynamics, ecology, or classification. The little that is now known about the basic nature of northern vegetation and flora permits only the making of primary surveys conducted in as much detail and as uniformly as possible. However, perhaps Professor Hare has been unfaithful to his "requirements of objectivity" on one point. The whole scheme of vegetation mapping from air-photographs depended on the recognition and grouping of physiognomic types, regardless of their successional or ecological relationships. In Table II, these physiognomic categories are described briefly and annotations about their physiographic positions are appended. To group them further into Moisture Series adds nothing to the information and compounds two different approaches to the grouping of vegetation. One must ask — how was a decision about the Moisture Series of a particular stand reached? The apparent answer is by "a scouting of its characteristic site", which implies the sort of personal judgement and postulating that the author is anxious to avoid. Hustich's grouping (Moisture Series) was firstly into forest *sites*, in the Finnish tradition; that is, it made a primary ecological postulate. That there is a good correspondence between the two "classifications" is not surprising, but it scarcely permits one to join the two approaches. Of course, it follows from this criticism that little would be lost by removing the Moisture Series considerations altogether.

The memoir is really the final chapter of a series of reports by the author and his associates, and a familiarity with these other publications is helpful, if not essential, for complete appreciation of the procedures and understanding of the data. They are referred to fully throughout the text, and the author takes pains to stress the collaborative nature of the whole endeavour. Deliberately, the author has avoided any considerations of the possible interpretation of his results, which further strengthens the work as a factual contribution lacking the clutter of personal judgements so common in ecological publications. Nevertheless, we look forward keenly to the promised interpretive treatment, for this investigation has raised many questions of interest.

One can find only praise for the clarity of exposition of the text — there are

few questions left unanswered regarding the precise objectives, methods, and results; even the usual reviewer's task of evaluating the contribution is made largely superfluous by the author's own critical assessments and suggestions for future research.

The illustrations deal chiefly with landform types, but together with those appearing in previous publications from the same project, they provide an excellent pictorial record of the information. The work is pleasingly printed and bound, and only one small printing error could be detected.

J. C. RITCHIE

WONDERS OF THE ARCTIC

By JACQUELYN BERRILL. *New York: Dodd, Mead. 1959. 9¼ x 7 inches, 94 pages, illustrated. $2.25*

Mrs. Berrill's book "Wonders of the Arctic" is written for a youthful audience (8-12 years). It opens with a general description of the arctic region and its seasonal changes. Then a chapter is devoted each to caribou and wolves, arctic foxes, lemmings, tundra hares, arctic birds, musk-oxen, polar bears, walrus, seals, and whales, giving a succinct account of their daily and family lives. A chapter on exploration, from Pytheas to the *Nautilus*, complete the book. Eskimos, Lapps, and other native peoples are only referred to in passing.

Mrs. Berrill's style is clear and simple. Unfortunately, on occasion she gets carried away (e.g. p. 63, "This is a bear [the polar bear] that never sees a plant in all its life . . ."); some inconsistencies have been allowed to creep in (e.g. p. 77, "Ice islands move through the ice pack in a counterclockwise direction"; p. 92, they are "traveling clockwise about the pole"); and not a few errors (e.g. p. 28, the Barren Grounds and the Tundra are considered the same; p. 36, ". . . and when the little fellows [lemmings] do venture out in the open, there is always a falcon, buzzard, owl, or skua gull ready to snatch them"; p. 42, ". . . the Eskimos, the people of the far North, kill hares for food and use their snow-white, furry skins to cover the sails of their boats so they can get closer to seals resting on the ice . . ."; p. 48, ". . . when the snow melts . . . there is simply no place for the water to go — so it becomes a bog"). Furthermore, although the Arctic Ocean has been referred to as a "mediterranean sea", it is open to debate whether it can be called "landlocked". On page 89 the impression is given that Alexander MacKenzie and Sir John Franklin were in the employ of the Hudson's Bay Company.

"Wonders of the Arctic" is handsomely illustrated with black and white pen-and-ink drawings. These have not been drawn from life, but are nonetheless pleasing. An adequate index is included. The volume is bound in a special reinforced library binding to withstand moisture and dirt, the pages have been strongly stitched to prevent them from coming out, and the cover has been reinforced so that it cannot be readily broken when bent, and will not come loose from the book — all admirable qualities for a children's book.

NORA CORLEY

THE WORLD OF THE ARCTIC

By FRANCES C. SMITH. *Philadelphia and New York: J. B. Lippincott Co.; Toronto: Longmans, Green and Co. 1960. 8¼ x 6 inches, 126 pages, 2 sketch maps, 16 illustrations. $3.50 in Canada.*

This slim volume is one of the latest in the "Portraits of the Nations" series, which attempt "to give young people compressed, authoritative and interesting profiles of the land, history, geography, and life" of various countries. "The World of the Arctic" is a slight departure from the others in that it discusses a geographical region rather than a political entity.

The reader is introduced to the region in a general outline, thence taken through three chapters concerning the history of discovery and exploration, followed by five chapters on Alaska, Canada's Western Arctic, the Arctic Archipelago, Greenland, and the Soviet

Arctic. Three chapters are devoted to the native peoples and two describe the fauna and flora. Modern exploration and scientific research are discussed in the final three chapters.

The generalization and the simple prose should make this book successful in its limited objective. On the whole, it is accurate and unlikely to leave young readers with false impressions. Unfortunately, the two maps are clumsy and scarcely adequate; indeed, one glaring transposition of Verkuta and Verkhoyansk is inexcusable. The statement that almost one-half of the world's Arctic area lies within the Soviet Union is misleading, especially as the introduction appears to accept the July 50° F. isotherm as the most suitable southern boundary. Ignoring water surface, Canada contains over 40 per cent of the total arctic area, compared with less than 20 per cent for the Soviet Union. Using another criterion, Canada's arctic tundra area exceeds that of the Soviet Union by some 200,000 square miles.

The sixteen glossy photographs are well chosen and reproduced, except for a caption that describes a large community in what is quite obviously a dense mixed-forest zone as being in the "far north". Despite these criticisms, the book is an adequate introduction to the Arctic for young readers.

J. KEITH FRASER

GEOGRAPHICAL NAMES IN THE CANADIAN NORTH

The Canadian Board on Geographical Names has adopted the following names and name changes for official use in the Northwest Territories and Yukon Territory. For convenience of reference the names are listed according to the maps on which they appear. The latitudes and longitudes given are approximate only.

M'Clintock Channel 67 NW and 67 NE
(Adopted March 3, 1960)

Denmark Bay	70°40′N.	103°25′W.	
Cloette Island	70°38′	103°29′	
Foster Point	71°20′	97°55′	not Point Foster
Cape Rendel	71°15′	96°25′	not Cape Rendell
Point Davison	70°40′	96°20′	not Point Davidson
Cape Admiral Collinson	70°19′	101°45′	not Cape Collinson
Cape Nicholas	70°30′	96°17′	not Cape Nicholas 1st

Fort Smith-Nonacho 75 SW
(Adopted March 3, 1960)

Powder Lake	61°05′N.	108°17′W.
Naskethey Lake	61°19′	109°33′
Heron Lake	61°18′	109°15′

Chart 7082 Cape Baring to Cambridge Bay
(Adopted March 3, 1960)
Altered applications

Rymer Point	69°01′N.	113°35′W.
Clouston Bay	69°02′	113°33′

Carp Lakes 85 P
(Adopted March 3, 1960)

Discovery (post office)	63°11′N.	113°54′W.

Camsell River 86 SW and 86 SE
(Adopted March 3, 1960)

MacIntosh Lake	65°46′N.	114°54′W.	not Rescue Lake nor Husky Lake nor Tern Lake

INDEX

A

Articles and Papers*
Reviews and Notes†

Age of the metamorphic complex of northernmost Ellesmere/Island: R. G. Blackadar, 51†
Alaska
  Investigation of the adjustment of the Eskimos at Barter Island, Alaska to rapid cultural changes: Norman A. Chance, 205†
  Glacial studies of the Mendenhall Glacier, Alaska, 204†
Aleksandrova, V. D., Some regularities in the distribution of the vegetation in the arctic tundra, 147*
Allophone, 24
Amphipods and trichinosis cycle, 119
Andrew Graham, Thomas Hutchins, and the first record of Peary's caribou: Richard Glover, 52†
Antarctic Scout; Richard Lee Chappell, *rev. of*, 140†
Apollonio, Spencer, the Arctic Institute Devon Island Expedition 1960, 270†
Application for the post of Executive Director of the Boreal Institute of the University of Alberta, 270†
Appointment of Dr. John C. Reed as executive Director of the Arctic Institute, 207†
Arctic ice island and ice shelf studies, Part II: A. P. Crary, 32*
Arctic Institute Devon Island Expedition 1960: Spencer Apollonio, 270†
Arctic Institute Range, 135
Asmous, V. C. (1891-1960): Marie Tremaine, 137†
Atlantic water, age of, 40

B

Bayard Glacier, 103
Behaviour and social organization of the wild bison of Wood Buffalo National Park, Canada: W. A. Fuller, 3*
Belcher, A. T., retirement of, 139†
Beluga, 113
Berendon Glacier, 103, 105
Berril, Jacquelyn, Wonders of the Arctic, *rev. of*, 275†
Biology
  Andrew Graham, Thomas Hutchins, and the first record of Peary's caribou: Richard Glover, 52†
  Behaviour and social organization of the wild bison of Wood Buffalo National Park, Canada: W. A. Fuller, 3*
  Bison, behaviour of, 3
  Bison bison athabascae, 3, *B. b. bison*, 3
  Bison, interspecific relations, 15
  Bison, relations to man, 17
  Bison, social organization, 10
  Carnivorous walrus and some arctic zoonoses: Francis H. Fay, 111*
  Clangula hiemalis, 201
  Eschrichtius glaucus, 257ff.
  Field studies on the behaviour of seaducklings: P. M. Driver, 201†
  Grey whale, 113, 257ff.
  Mergus serrator, 201
  Recent records of the California grey whale (*Eschrichtius glaucus*) along the north coast of Alaska: W. M. Maher, 257*
  Somateria mollissima, 201
  Wood buffalo, 3
Bison bison athabascae, 3, *B. b. bison*, 3
Bison, wild, 3
Blackadar, R. G., The age of the metamorphic complex of northernmost Ellesmere Island, 51†
Botany
  Forest-tundra, 216
  Hudson Bay Lowlands, 221
  Lowland Complex, 226
  Moss-Muskeg Type, 224
  Open Coniferous Forest, 218
  Some regularities in the distribution of the vegetation in the arctic tundra: V. D. Aleksandrova, 147*
  Some soil fungi from an Alaskan tundra area: Wm. Bridge Cooke and H. T. Fournelle, 266†
  The vegetation of northern Manitoba V. Establishing the major zonation: J. C. Ritchie, 211*
  Transition Type, 223
  Treeless Bog Type, 225
  Tundra, 147, 215
Botulism, 230ff.
Brown, R. J. E., The distribution of permafrost and its relation to air temperature in Canada and the U.S.S.R., 163*

C

Carnivorous walrus and some arctic zonoses: Francis H. Fay, 111*
Chance, Norman A., Investigation of the adjustment of the Eskimos at Barter Island, Alaska to rapid cultural changes, 205†
Chappell, Richard Lee, Antarctic Scout, *rev. of*, 140†
Chickamin Glacier, 107
Clangula hiemalis, 201
Clark, Don B., A strain gauge technique for the dynamic measurement of ice, 123*
Clostridium botulinum, 231 *passim*
Collin, A. E., Oceanographic observations in the Canadian Arctic and the adjacent Arctic Ocean, 194†
Cook, Frank A., Periglacial-geomorphological investigations at Resolute, 1959, 132†
Cooke, Alan, *rev. of* Dictionary of discoveries, 59†
Cooke, Wm. Bridge, and H. T. Fournelle, Some soil fungi from an Alaskan tundra area, 266†
Cornell Medical Index Questionnaire (CMI), 205
Crary, A. P. Arctic ice island and ice shelf studies, Part II, 32*

Crary, A. P., *rev. of* Antarctic Scout, 140†
Correction to "note added in proof" p. 218, Vol. 12, 56†

D

Delphinapterus leucas, 113
Devon Island Expedition 1960, the arctic Institute, 270†
Directory of discoveries, *rev. by* Alcan Cooke, 59†
Distribution, the, of permafrost and its relation to air temperature in Canada and the U.S.S.R.: R. J. E. Brown, 163*
Dolman, Claude E., Type E botulism: a hazard of the north, 230*
Driver, P. M., Field studies on the behaviour of sea-ducklings, 201†

E

Epidemiology and geographic distribution of type E botulism 234ff.
Erosion caused by precipitation, 134
Eschrichtius glaucus 113, 257ff.
Eskimos
  Language, 20
  Eskimo Graphic Art Folder, 55
  Investigation of the adjustment of the Eskimos at Barter Island, Alaska to rapid cultural changes; Norman A. Chance, 205†
  Prints, a new handicraft, 55

F

Fay, Francis H., Carnivorous walrus and some arctic zoonoses, 111*
Fellows of the Arctic Institute, list of the, 67
Field studies on the behaviour of sea-ducklings: P. M. Driver, 201†
FitzGerald, Colonel, receives honorary degree, 139†
Foraminifera as indicators of marine submergence, 187
Forest-Tundra, 216
Fournelle, H. T., *see* Cooke, Wm. Bridge, 266
Fraser, J. Keith, New map of Northwest Territories and Yukon Territory, 132†
Freeze-thaw cycles at Resolute, N. W. T., 133
Fuller, W. A., Behaviour and social organization of the wild bison of Wood Buffalo National Park, Canada, 3*

G

Gagné, Raymond C., On the importance of the phonemic principle in the design of an orthography, 20*
Geographical names in the Canadian north, 65, 142, 208, 276
Geomorphology
  Periglacial-geomorphological investigations at Resolute, 1959: Frank A. Cook, 132†
Geology
  Age of the metamorphic complex of northernmost Ellesmere Island: R. G. Blackadar, 51†
  The distribution of permafrost and its relation to air temperature in Canada and the U.S.S.R.: R. J. E. Brown, 163*
Glaciology
  Glaciological studies of the Mendenhall Glacier, Alaska, 204†
  Photogrammetric and glaciological studies of Salmon Glacier, 75
Glover, Richard, Andrew Graham, Thomas Hutchins, and the first record of Peary's caribou, 52†
Goodfellow, Joan, missing on Great Bear Lake, 272†
Governors of the Arctic Institute, list of the, 67
Grey whale, 113, 257ff.

H

Hare, F. Kenneth, A photo-reconnaissance survey of Labrador-Ungava, *rev. of*, 273*
Harp, Jr., Elmer, *rev. of* The neolithic age in eastern Siberia, 60†
Haumann, Dieter, Photogrammetric and glaciological studies of Salmon Glacier, 75*
Heat balance of arctic basin waters, 38
History of polar exploration, *rev. by* Jim Lotz, 57†
Honorary Members of the Arctic Institute, list of the, 67
Hudson Bay Lowlands, 221
Hypervitaminosis and carnivorous walrus, 114

I

Ice
  Arctic ice island and ice shelf studies, Part II: A. P. Crary, 32*
  A strain gauge technique for the dynamic measurement of ice: Don B. Clark, 123*
  Ellesmere Island ice shelf project: R. B. Sagar, 271†
  Growth of floating ice sheets, 32
  History of ice shelves, 41
  Ice islands, 48
  Surface features of ice shelves, 46
Institute News
  Appointment of Dr. John C. Reed as Executive Director of the Arctic Institute, 207†
  Arctic Institute Devon Island Expedition 1960: Spencer Apollonio, 270†
  Award of Institute grants, 62†
  Ellesmere Island Ice shelf project 1960: R. B. Sagar, 271†
  Colonel FitzGerald receives honorary degree, 139†
  Gifts to the Library, 62†, 140†, 207†, 272†
  Missing field party on Great Bear Lake, 272†
  Retirement of Mr. A. T. Belcher, 139†
  Technical papers of the Arctic Institute, 140†, 273†
Investigation of the adjustment of the Eskimos of Barter Island, Alaska to rapid cultural changes: Norman A. Chance, 205†
Iyola, 56

K

Kananginak, 56
Kirwan, L. P., The white road; a history of polar exploration, *rev. of*, 57†
Kröger, Annemarie, missing on Great Bear Lake, 272
Kunu, 56

L

Langnas, J. A., Dictionary of discoveries, *rev. of*, 59†
Linguistics
In the importance of the phonemic principle in the design of an orthography: Raymond C. Gagné, 20*
Lotz, Jim, *rev. of* The white road, a history of polar exploration, 57†
Lowland Complex, 226

M

Maher, W. M., Recent records of the California grey whale *(Eschrichtius glaucus)* along the north coast of Alaska, 257*
Maps
Arctic Ocean, lines of equal heat, 39
Bathymetric map of northern Canada, 196
Distribution of permafrost in the U.S.S.R., 168
Distribution of permafrost in Canada, 169
Freezing indices in Canada, 174
Foci of endemic type E botulism in northern Japan, B.C., and Alaska, 249
Location map of Melville Peninsula, 179
Locations of oceanographic stations, northern Canada, 195
Locations of ground temperature installations, 171
Map of northern Manitoba showing the main physiographic regions, 212
Map showing the vegetation zones of northern Manitoba, 210
Marine shells and strand-lines on Melville Peninsula, 182
Mean annual air temperatures in Canada, 172
Mosaic map of Salmon Glacier, 87
Northern Ellesmere Island, locations of samples for radiocarbon dating, 42
North Pacific Ocean showing main currents, 246
Perched boulders in Melville Peninsula, 188
Possible source of T-3, 45
Post-glacial limit of marine submergence in Melville Peninsula, 192
Reports of permafrost, 165
Salmon Glacier, *in pocket*, No. 3
Salmon Glacier area, 74
September ice conditions in northern Canada, 197
Sites of botulism occurrences in B.C., Alaska, and the Yukon, 237
Sites of botulism outbreaks in Northwest Territories and Labrador, 239
Southern boundary of permafrost in Canada, 164
Summer range of California grey whale, 258
Thawing indices in Canada, 175
Undisturbed ground moraines in Melville Peninsula, 186
Wood Buffalo National Park, 2
Zonation of Novaya Zemlya, 158
Zones of permafrost, 166
Marine shells as indicators of marine submergence, 180
Mecham River, run-off characteristics of, 133
Mendenhall Glacier, 204
Mergus serrator, 201
Michael, Henry N., The neolithic age in eastern Siberia, *rev. of*, 60†
Moraine, undisturbed ground, as indicator of marine submergence, 183
Moss-Muskeg Type, 224

N

Neolithic age in eastern Siberia: Henry N. Michael, *rev. of*, 60†
New map of Northwest Territories and Yukon Territory: J. Keith Fraser, 132†
Niviaksiak, 56
Notes
Age of the metamorphic complex in northernmost Ellesmere Island: R. G. Blackadar, 51†
Andrew Graham, Thomas Hutchins, and the first record of Peary's caribou: Richard Glover, 52†
Application for the post of Executive Director of the Boreal Institute of the University of Alberta, 270†
Appointment of Dr. John C. Reed as Executive Director of the Arctic Institute, 207†
Colonel FitzGerald receives honorary degree, 139†
Field studies on the behaviour of seaducklings: P. M. Driver, 201†
Glaciological studies of the Mendenhall Glacier, Alaska, 204†
Investigation of the adjustment of the Eskimo of Barter Island, Alaska to rapid cultural changes: Norman A. Chance. 205†
New polar training ship, 136†
New map of the Northwest Territories and Yukon Territory; J. Keith Fraser, 132†
Oceanographic observations in the Canadian Arctic and the adjacent Arctic Ocean: A. E. Collin, 194†
Periglacial-geomorphological investigations at Resolute, 1959; Frank A. Cook, 132†
Note on cover picture, 55†
Some soil fungi from an Alaskan tundra area: Wm. Bridge Cooke and H. T. Tournelle, 266†
Victoria Land traverse, Antarctica, 1959–60: John G. Weihaupt, 135†
Novaya Zemlya, 148 *passim*

Novaya Zemlya
Climate, 149
Flora, 149ff.
Vegetation zones, 151ff.

O

Obituary
V. C. Asmous (1891-1960): Marie Tremaine, 137†
Oceanography
Oceanographic observations in the Canadian Arctic and adjacent Arctic Ocean: A. E. Collin, 194†
Odobenus rosmarus, 111ff.
On the importance of the phonemic principle in the design of an orthography; Raymond C. Gagné, 20*
Open Coniferous Forest, 218
Ornithology
Field studies on the behaviour of seaducklings: P. M. Driver, 201†

P

Parry Channel, longitudinal profile of, 199
Parry Channel, temperature and salinity in, 200
Perched boulders as indicators of marine submergence, 186
Permafrost
Distribution and air temperature, 171
Distribution and origin, 163
Distribution in Russia, 168
Russian mapping of, 167
Phonemic principle, 20
Phoneme, 24
Photogrammetric and glaciological studies of Salmon Glacier: Dieter Haumann, 75*
Photogrammetry
Terrestrial photogrammetry, 82
Aerial photogrammetry, 80
Photo-reconnaissance survey of Labrador-Ungava: F. Kenneth Hare, *rev. of*, 273†
Precipitation as an agent of erosion, 134

R

Recent records of the California grey whale *(Eschrichtius glaucus)* along the north coast of Alaska: W. M. Maher, 257*
Reed, Dr. John C., appointment of, as Executive Director, 207†
Rennick Glacier, 135
Reviews
Antarctic Scout, *by* A. P. Crary, 140†
A photo-reconnaissance survey of Labrador-Ungava, *by* J. C. Ritchie, 273†
Directory of discoveries, *by* Alan Cooke, 59†
Neolithic age in eastern Siberia, *by* Elmer Harp, Jr., 60†
White road; a history of polar exploration, *by* Jim Lotz, 57†
Wonders of the Arctic, *by* Nora Corley, 275†
World of the Arctic, *by* J. Keith Fraser, 275†
Ridge and through system of ice shelves, 46
Rimja Dan, new polar training ship, 136†
Ritchie, J. C., *rev. of* a photo-reconnaissance survey of Labrador-Ungava, 273†
Ritchie, J. C., the vegetation of northern Manitoba V. Establishing the major zonation, 211*

S

Sagar, R. B., Ellesmere Island Ice Shelf Project, 1960, 271†
Salmon Glacier, 75
Smith, Frances C., the world of the Arctic, *rev. of*, 275†
Snow depth at Canadian arctic stations, 37
Somateria mollissima, 201
Some regularities in the distribution of the vegetation in the arctic tundra: V. D. Aleksandrova, 147*
Strain gauge technique for the dynamic measurement of ice: Don B. Clark, 123*
Strand-lines as indicators of marine submergence, 183
Summit Lake, 91, 95, 106
Surface features of ice shelves, 46

T

Through Glacier, 107
Tide Lake, 95, 104
Transition Type, 223
Treeless Bog Type, 225
Tremaine, Marie, Obituary of V. C. Asmous, 137†
Trichinella spiralis, 111ff.
Trichinosis, 115, 231, 232
Trichinosis cycle, the arctic, 118
Tundra, 147, 215
Type E botulism: a hazard of the north: Claude E. Dolman, 230*

V

Vegetation, the, or northern Manitoba V. Establishing the major zonation: J. C. Ritchie, 211*
Victoria Land traverse, Antarctica, 1959-60: John G. Weihaupt, 135†

W

Walrus, 111ff.
Weihaupt, John G., Victoria Land traverse, Antarctica, 1959-60, 135†
White road; a history of polar explorations: L. P. Kirwan, *rev. by* Jim Lotz, 57†
Wonders of the Arctic: Jacquelyn Berrill, *rev. by* Nora Corley, 275†
Wood Buffalo National Park, 3
World of the Arctic: Frances C. Smith, *rev. by* J. Keith Fraser, 275†

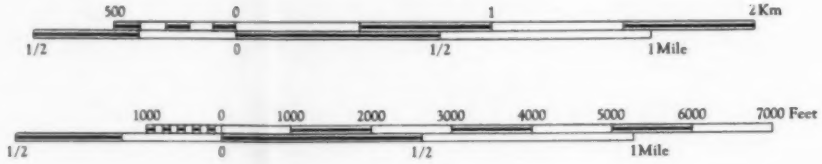
Z

Zones of vegetation, 214

SALMON GLACIER

BRITISH COLUMBIA

SCALE 1:25,000



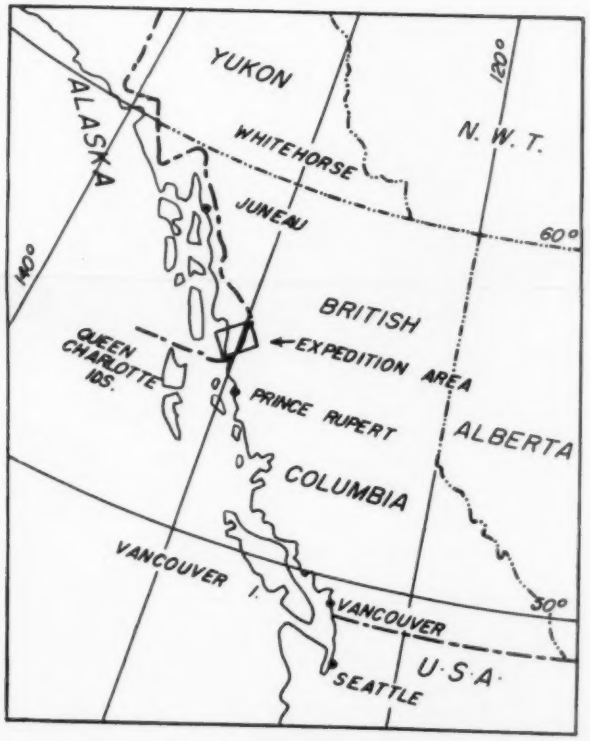
ALL ELEVATIONS IN METRES ABOVE MEAN SEA LEVEL
CONTOUR INTERVAL 20 METRES

Conversion from metres to feet

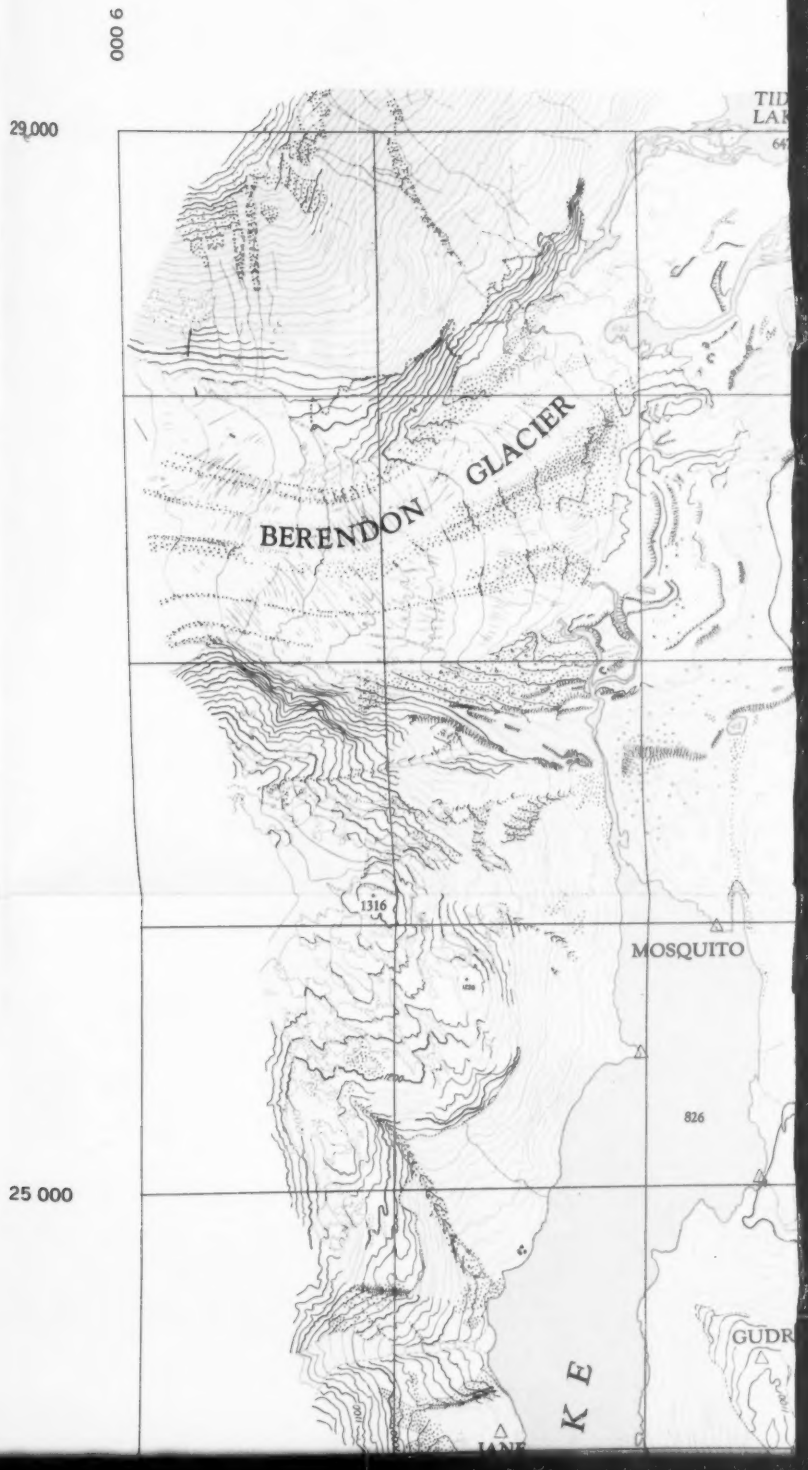
m	ft	m	ft	m	ft	m	ft	m	ft	m	ft
100	328	600	1969	1100	3609	1600	5249	2100	6890	2600	8530
200	656	700	2297	1200	3937	1700	5577	2200	7218	2700	8858
300	984	800	2625	1300	4265	1800	5906	2300	7546	2800	9186
400	1312	900	2953	1400	4593	1900	6234	2400	7874	2900	9514
500	1640	1000	3281	1500	4921	2000	6562	2500	8202	3000	9843

REFERENCE

- Contours on rock or bare terrain
- Contours on vegetation
- Contours on glacier
- Rock outline
- Glacier outline
- Snow outline
- Trails
- Terraces



LOCATION DIAGRAM



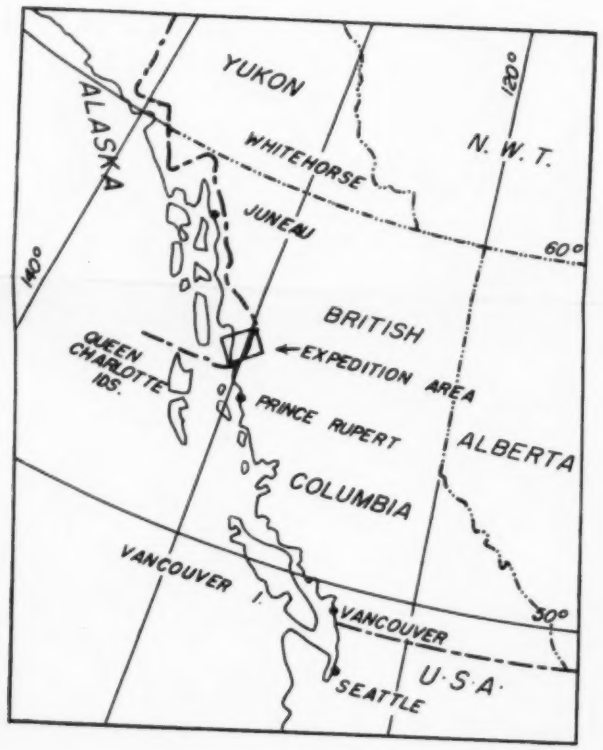
ACIER

2 Km
1 Mile

6000 7000 Feet
1 Mile

A LEVEL

ft
30
58
86
14
43



LOCATION DIAGRAM

30 000

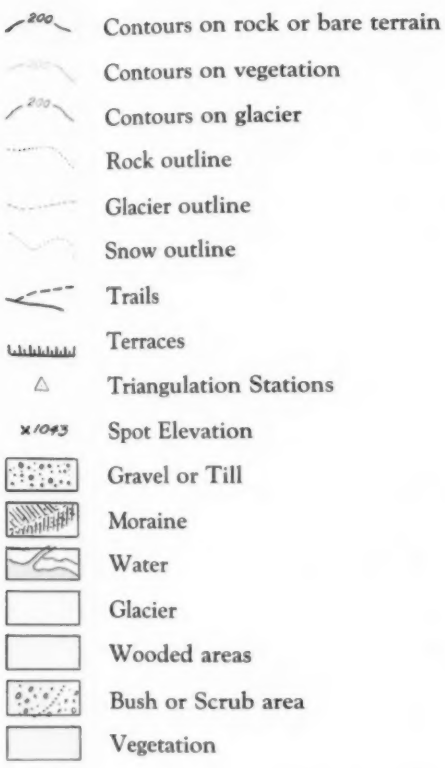
9 000

29 000

25 000

14 000
29 000
25 000
TIDE
LAKE
647
BERENDON GLACIER
1316
MOSQUITO
826
GUDRUN
JANE

REFERENCE



The field work was done by D. Haumann of the National Research Council during the Second Salmon Glacier Expedition by the University of Toronto in the summer of 1957.

The local triangulation net was tied to the points CANTU and SEA 14, established by the Surveys and Mapping Branch, Department of Lands and Forests, British Columbia and to the International Boundary Point 17 on Mt. Upshur.

The origin of the local triangulation net is 56°00′ north latitude and 130°15′ west longitude.

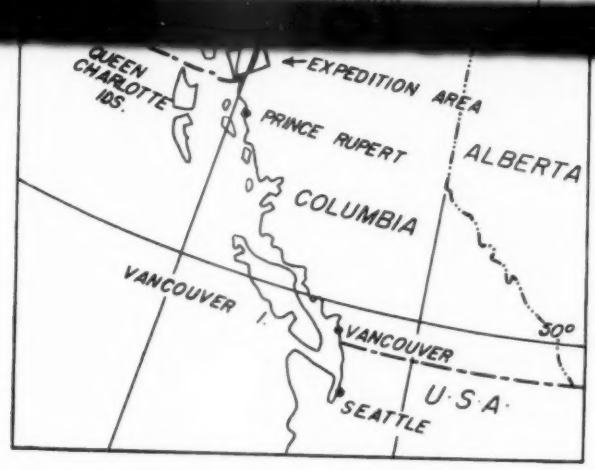
The vertical datum is based on CANTU, elevation 416.97 metres above mean sea level.

Aerial photography by Department of Lands and Forests, B.C., Augest, 1957.

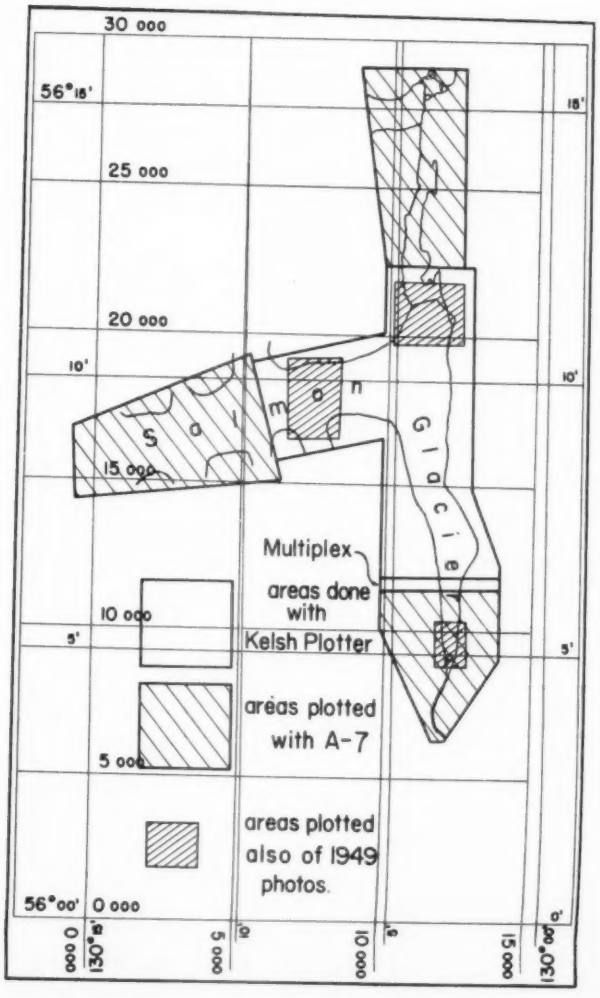
Calculation, photogrammetric evaluation and plotting by D. Haumann and G. Lempereur, N.R.C.

Draughting by D. Honegger, N.R.C.

Names of glaciers, mountains, rivers, etc., according to local information.



LOCATION DIAGRAM



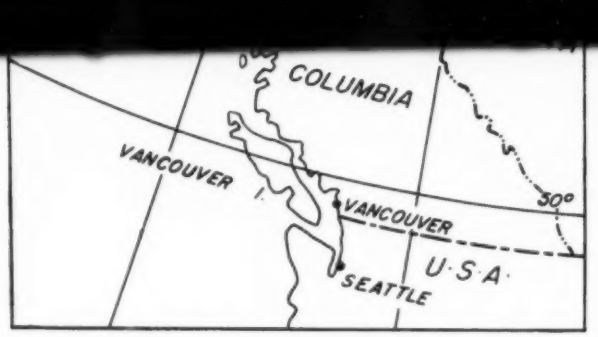
KEY DIAGRAM TO PLOTTING

25 000

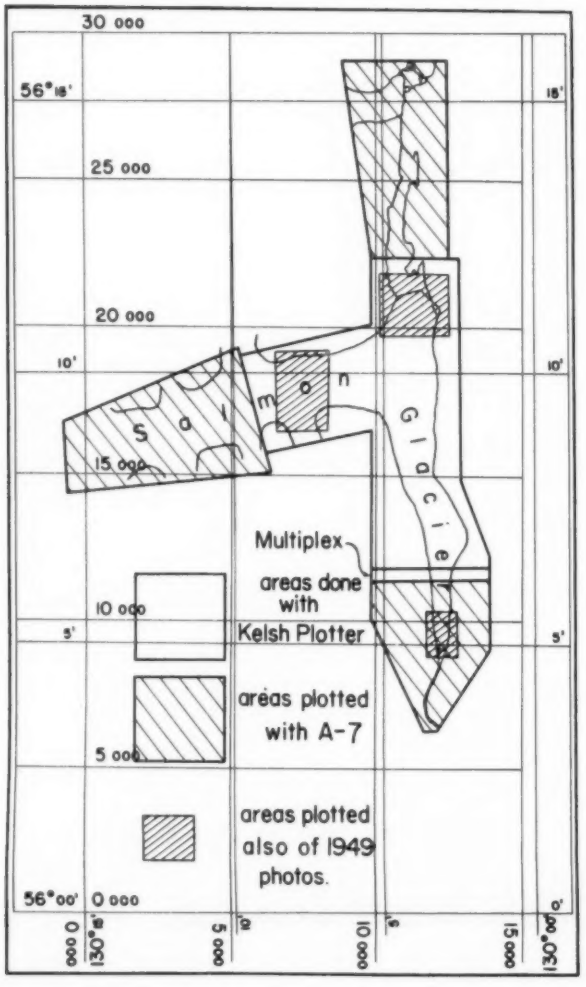
BETTY △

HERMAPHRODITE △

GR



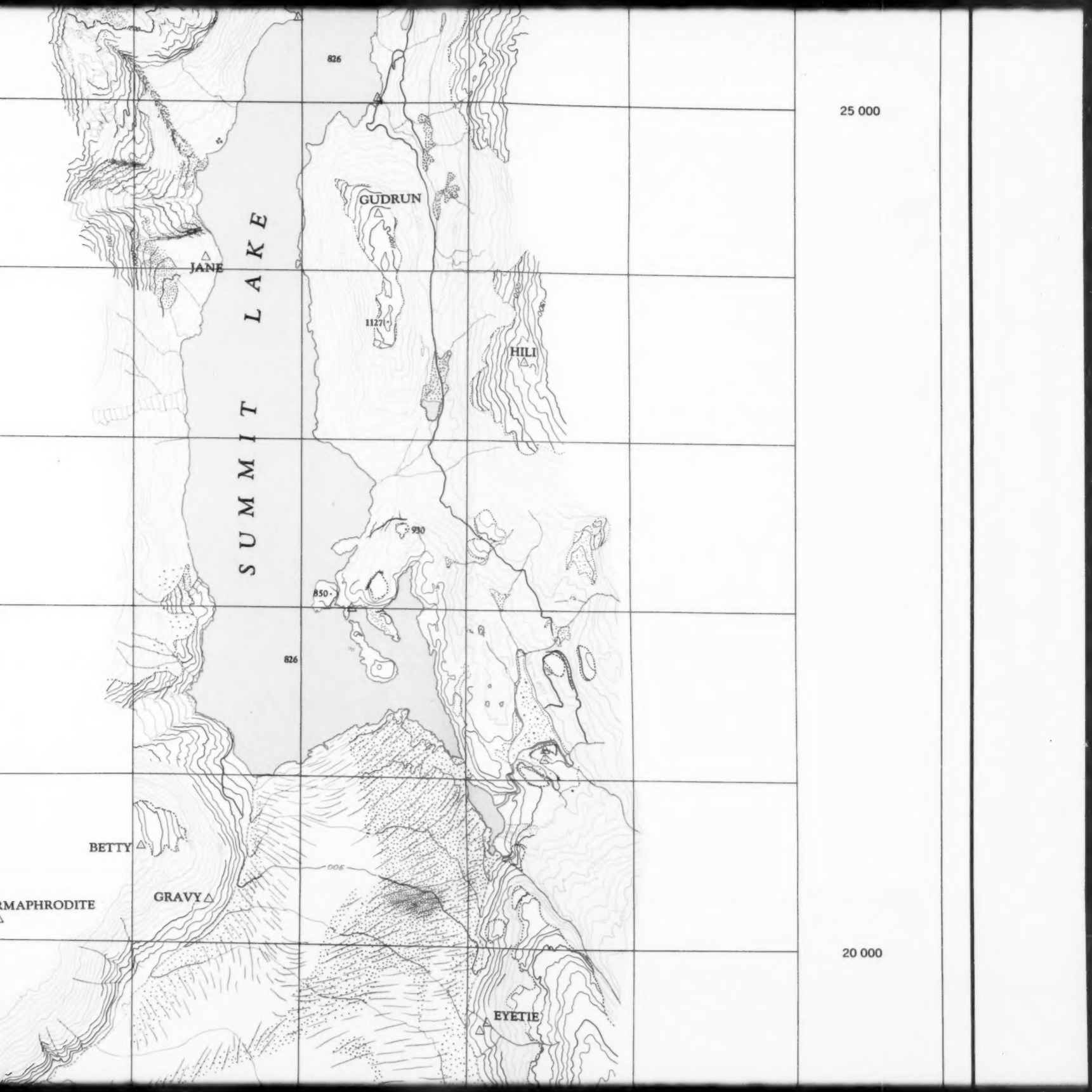
LOCATION DIAGRAM



KEY DIAGRAM TO PLOTTING

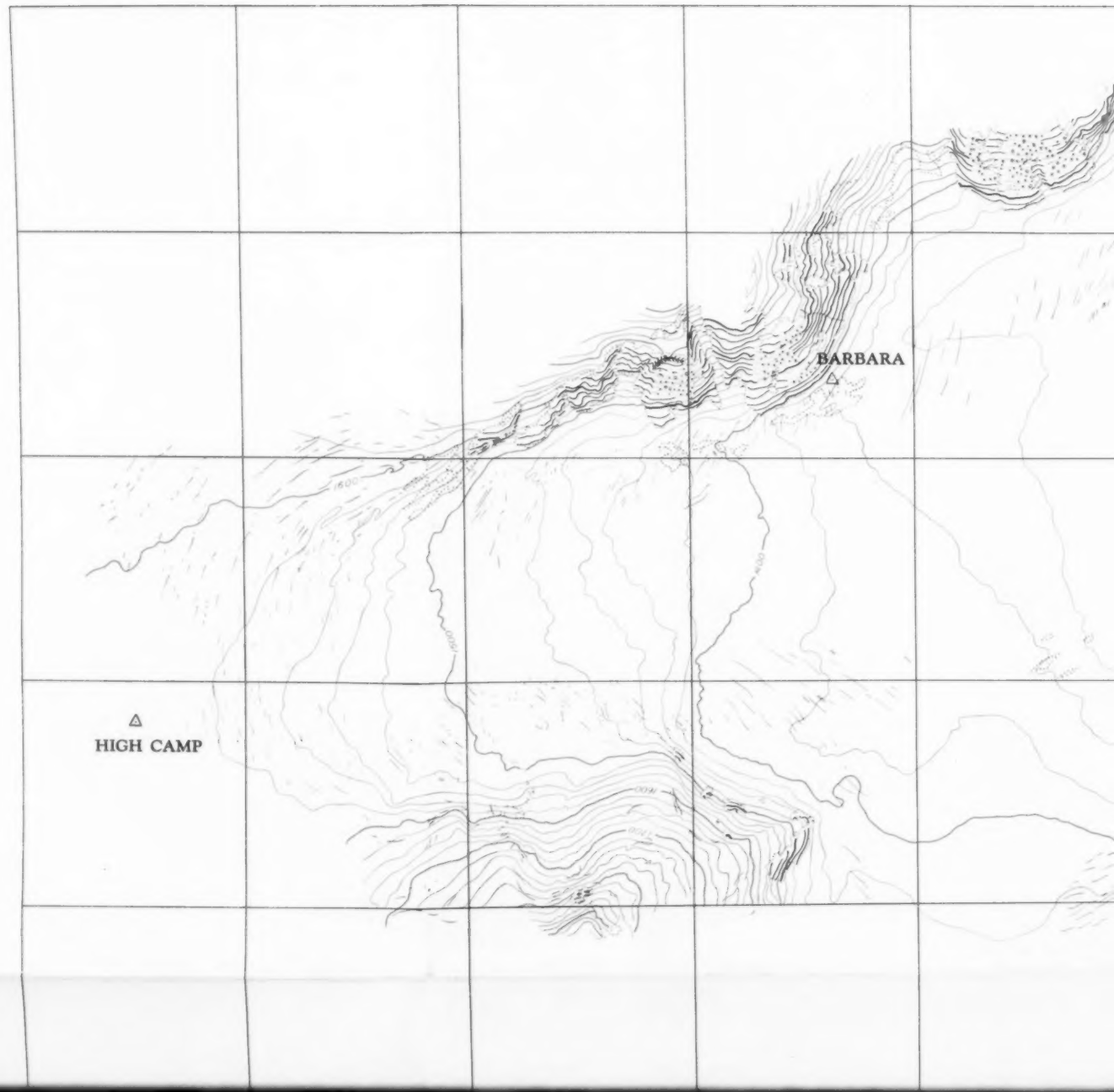
25 000

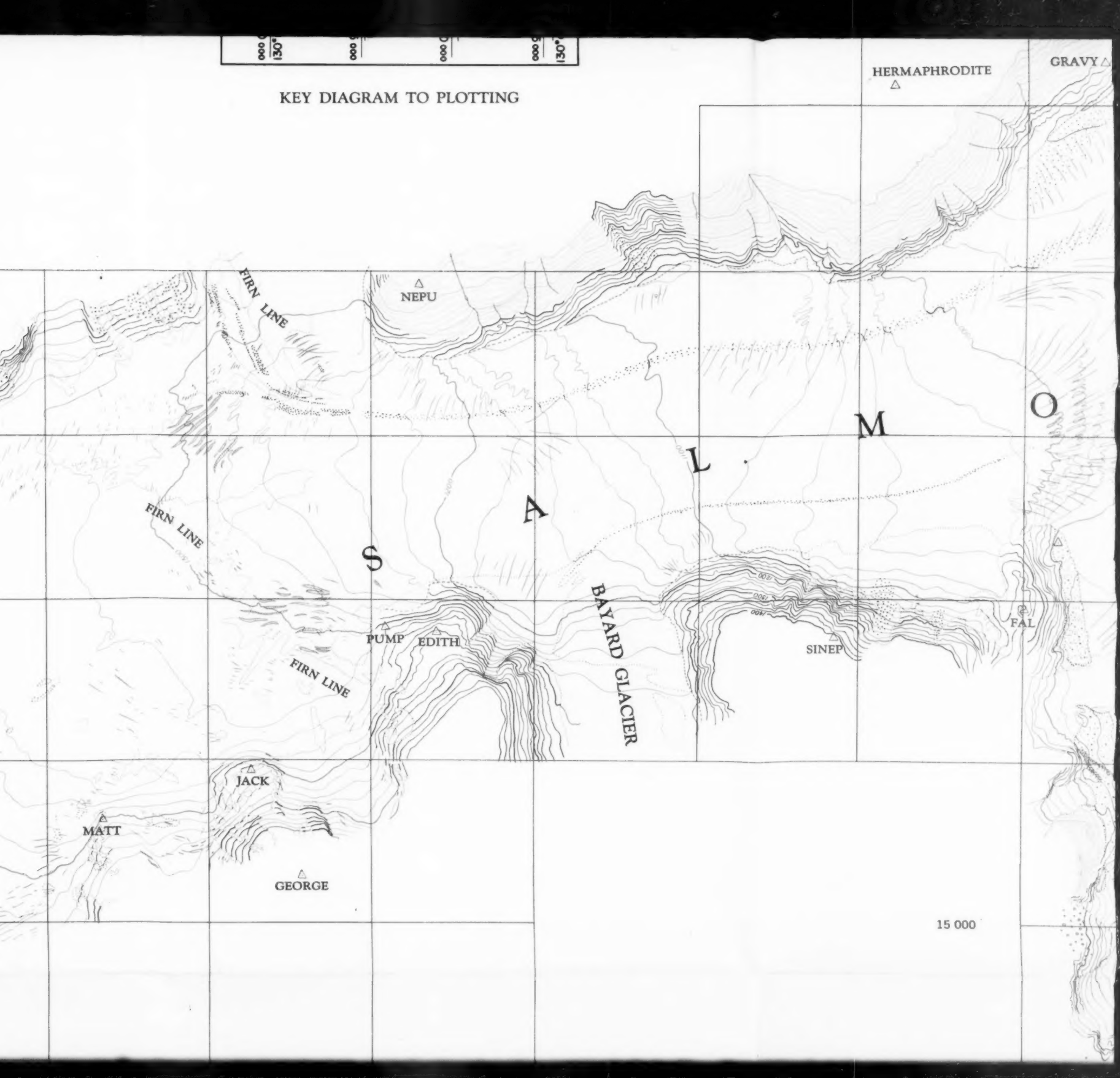
HERMA
△


826
GUDRUN
JANE
SUMMIT LAKE
1127
HILI
930
850
826
BETTY
GRAVY
RMAPHRODITE
EYETIE
25 000
20 000

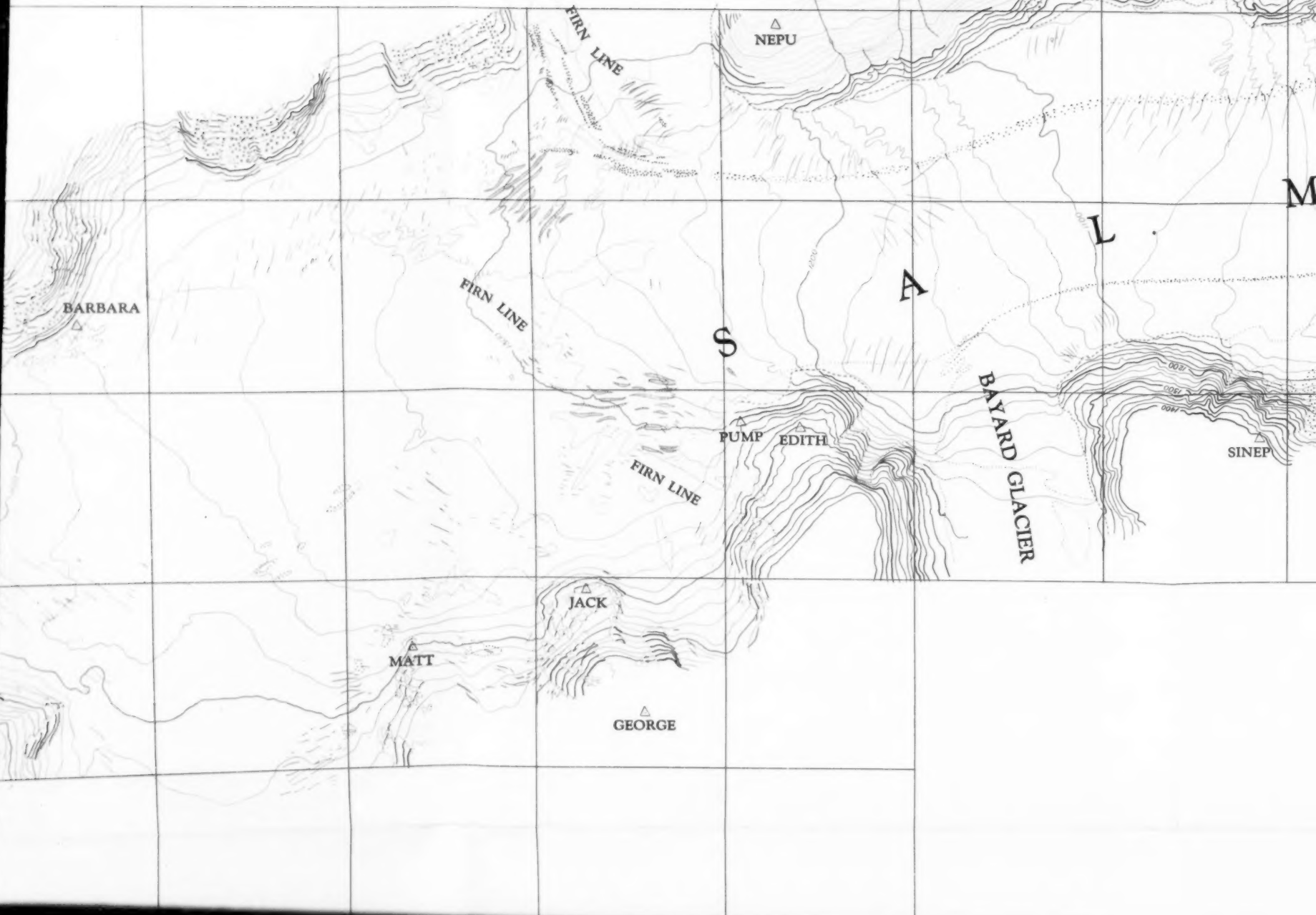
Names of glaciers, mountains, rivers, etc., according to local information.

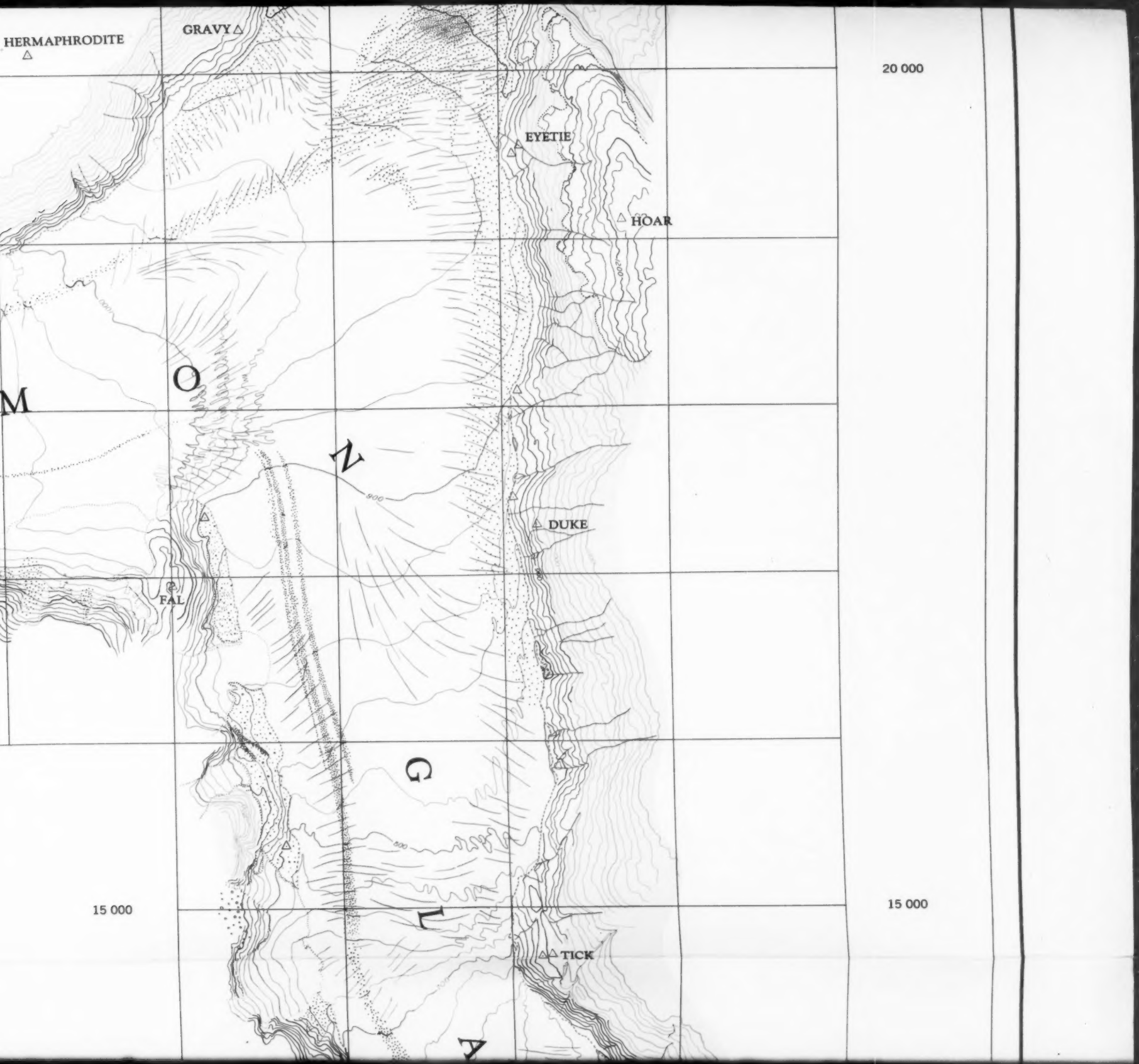
19 000

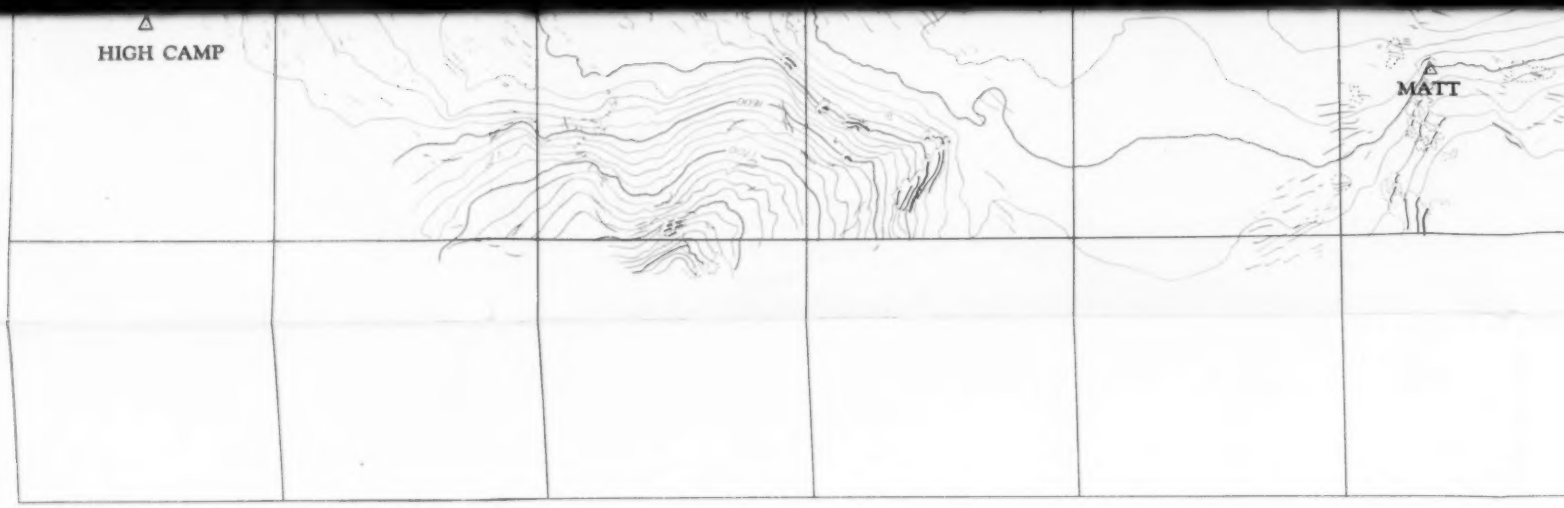



KEY DIAGRAM TO PLOTTING
HERMAPHRODITE
GRAVY
NEPU
FIRN LINE
FIRN LINE
FIRN LINE
PUMP
EDITH
BAYARD GLACIER
SINEP
FAL
JACK
MATT
GEORGE
15 000

KEY DIAGRAM TO PLOTTING

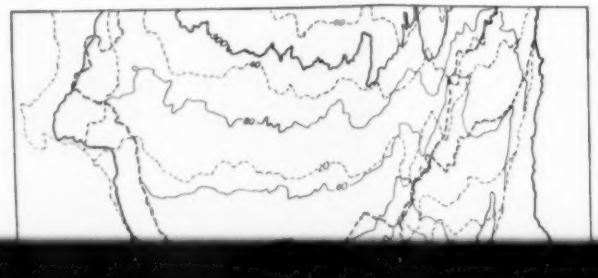


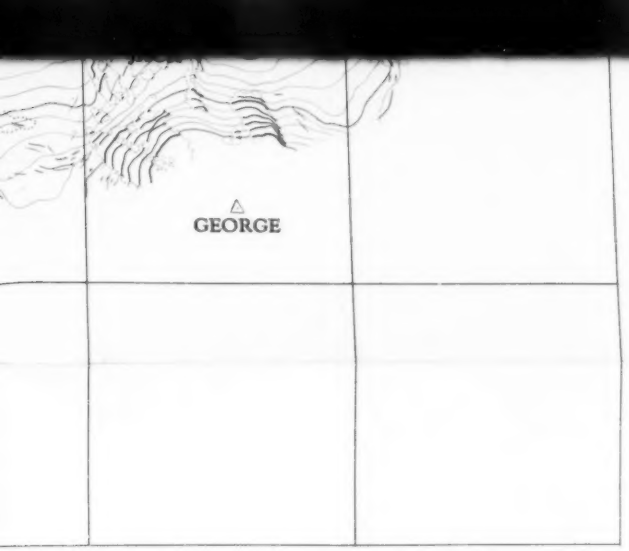

HERMAPHRODITE
GRAVY
20 000
EYETIE
HOAR
M
O
N
G
O
L
I
A
DUKE
FAL
TICK
15 000
15 000



Ablation Studi

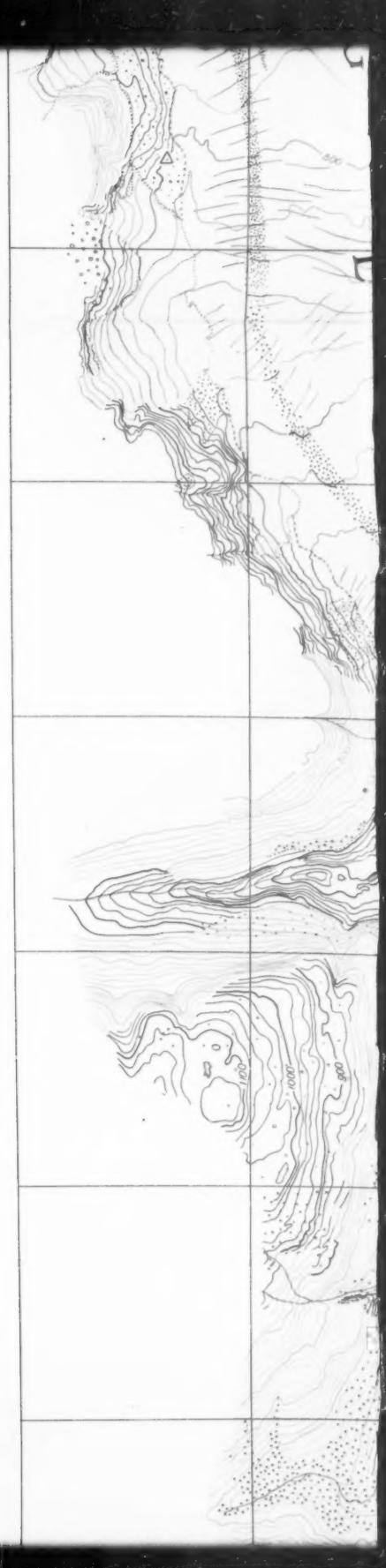
The broken contours show the stage of glaci
the stage in August 1957. The distribution o





5 000

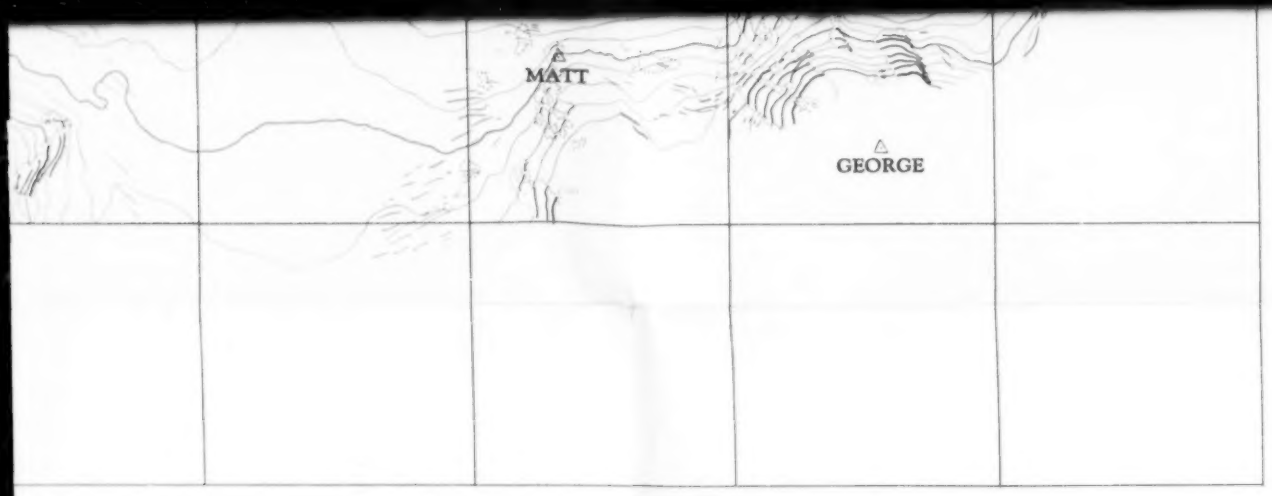
15 000



Studies on Salmon Glacier

f glaciation in September 1949, the solid contours indicate
ation of these areas is shown on the key map.

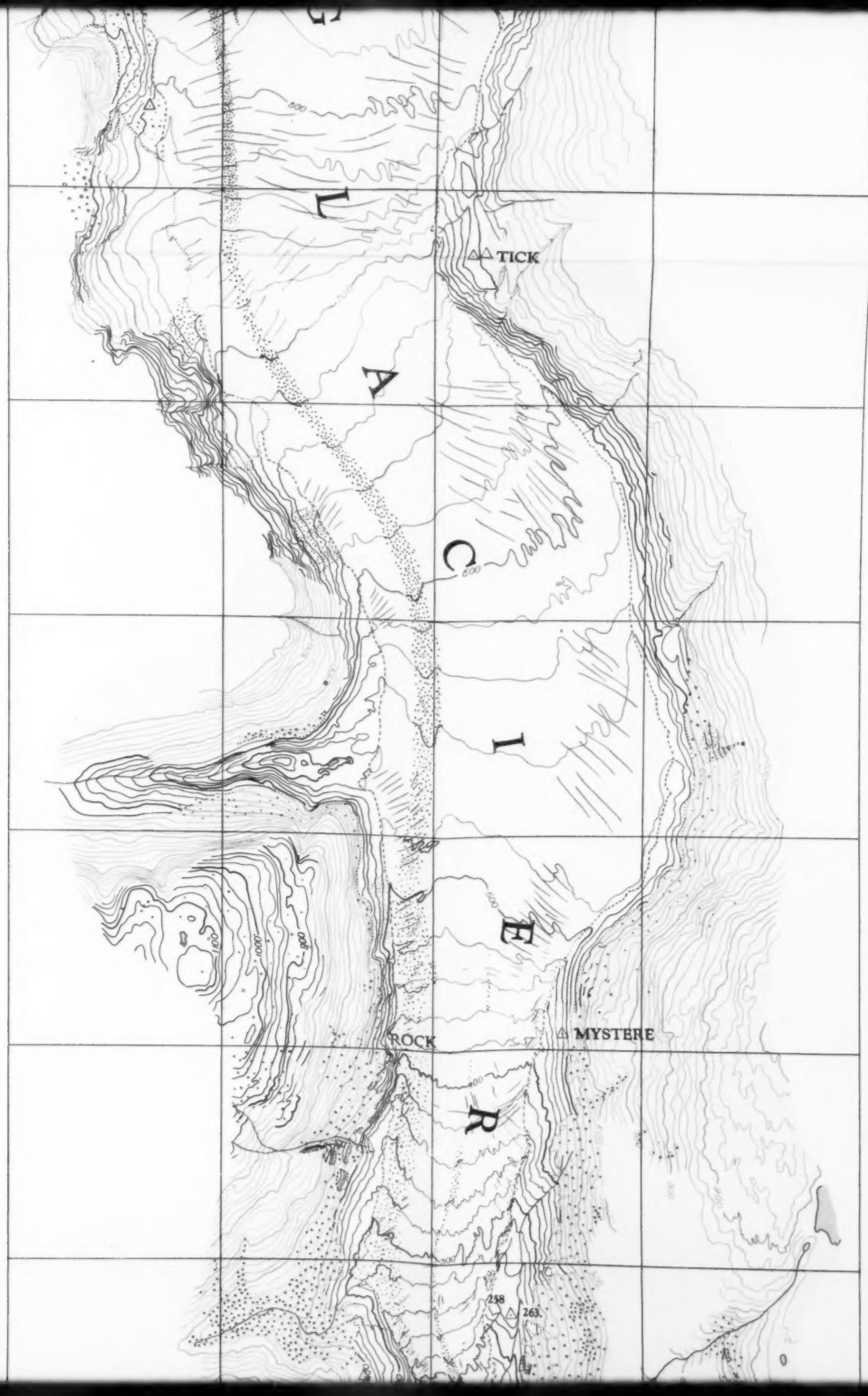
10 000

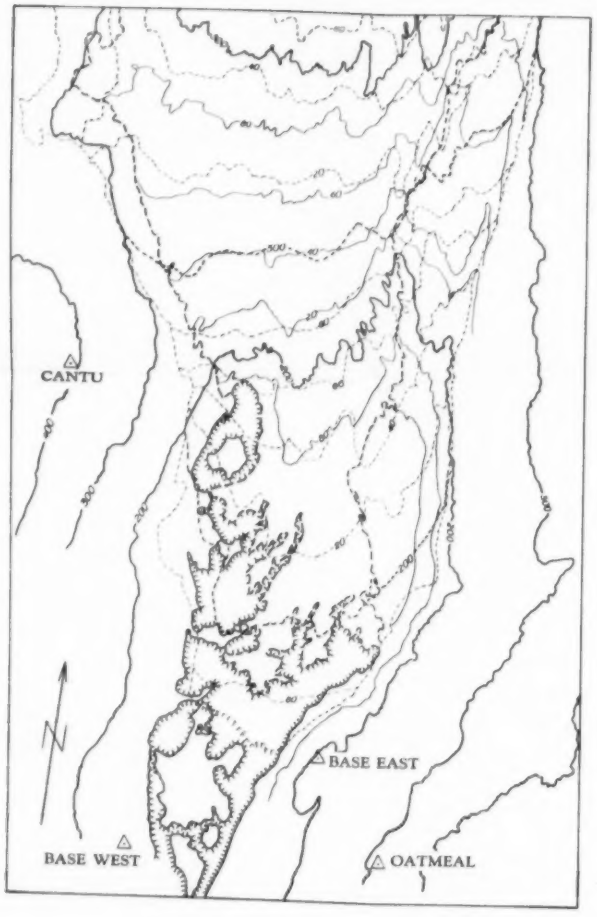


5 000

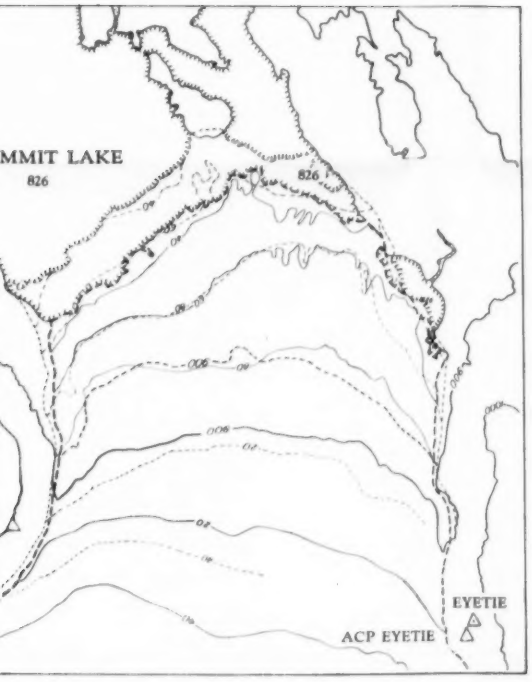
Ablation Studies on Salmon Glacier

The broken contours show the stage of glaciation in September 1949, the solid contours indicate the stage in August 1957. The distribution of these areas is shown on the key map.

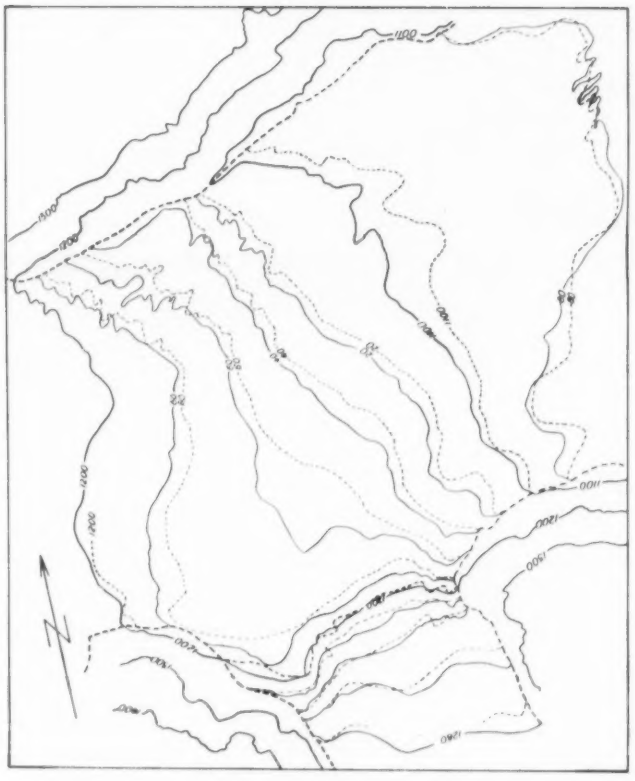

15 000
15 000
TICK
GLACIER
ROCK
MYSTERE
10 000
10 000
258
263



South Snout
Scale 1:12,500



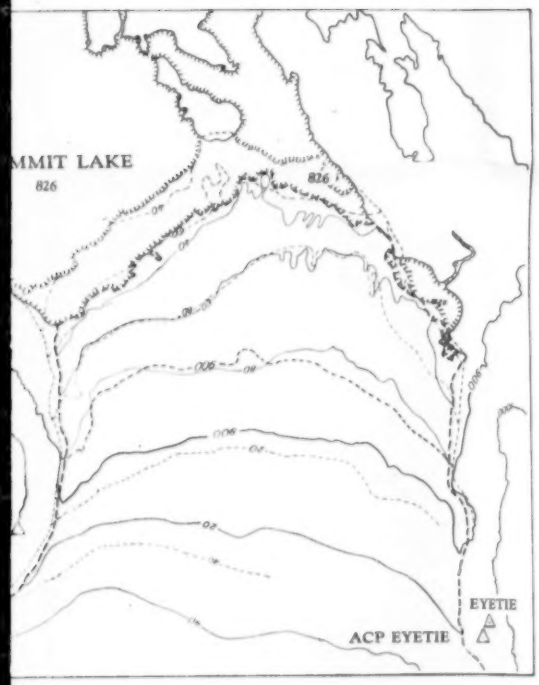
North Snout
Scale 1:25,000



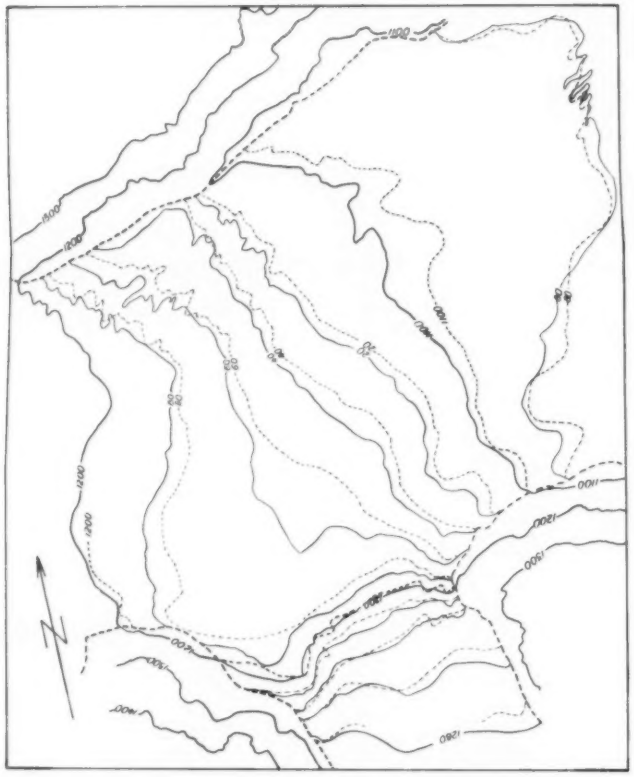
Central Tongue, joining area of Bayard Glacier
Scale 1:25,000

10 000

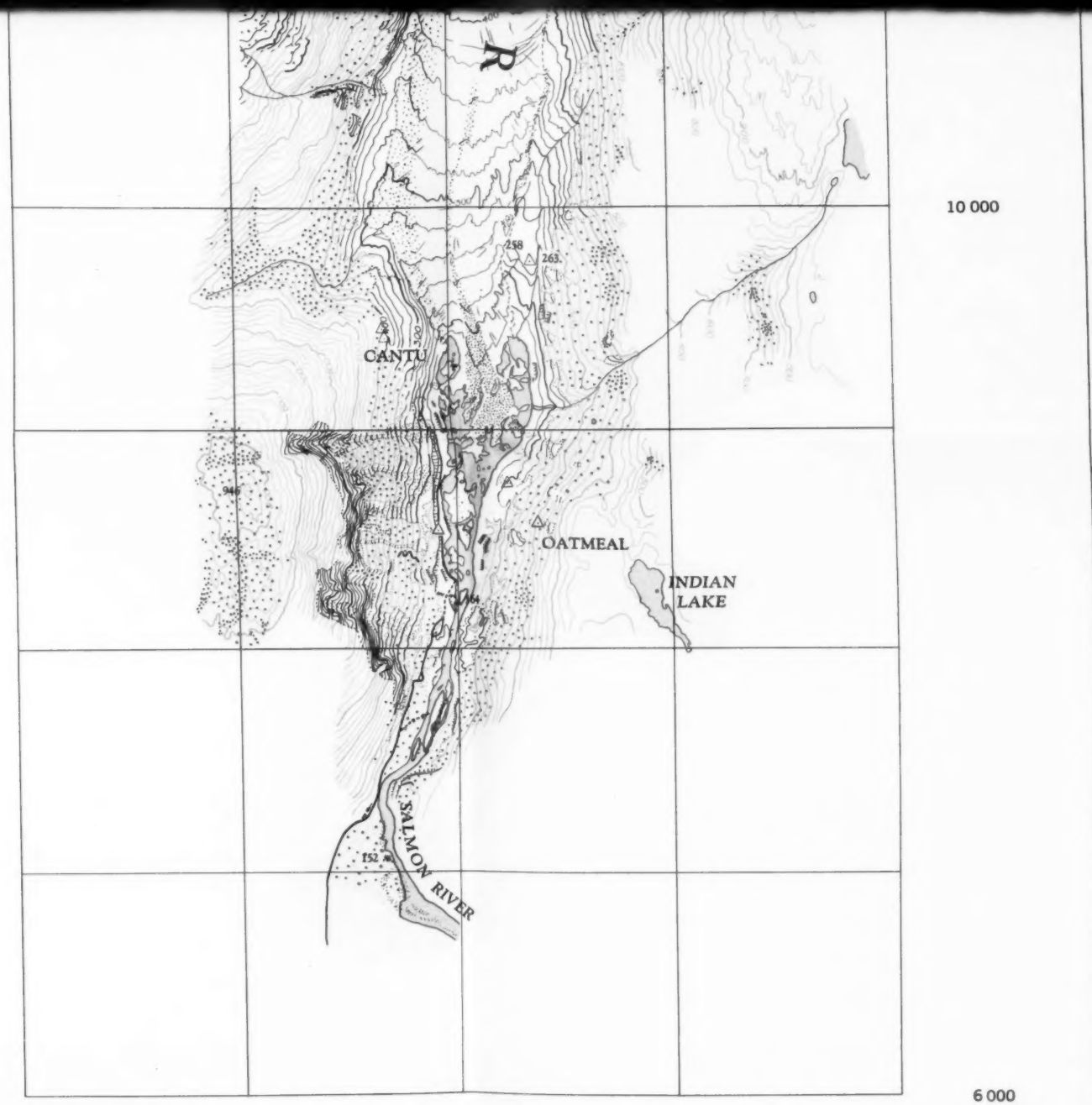
6 000



North Snout
Scale 1:25,000



Central Tongue, joining area of Bayard Glacier
Scale 1:25,000



Reproduced and printed by the Army Survey Establishment, R.C.E. 1959.